VALASIA ISAAKIDOU

PHD THESIS

BONES FROM THE LABYRINTH: FAUNAL EVIDENCE FOR MANAGEMENT AND CONSUMPTION OF ANIMALS AT NEOLITHIC AND BRONZE AGE KNOSSOS, CRETE

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Institute of Archaeology
UNIVERSITY COLLEGE
LONDON

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

ABSTRACT

Animals feature extensively in the iconography and written records of Bronze Age Crete, and in archaeological debates ranging from initial colonisation in the 7th millennium BC, through expansion of settlement across the island in the 4th-3rd millennia, to surplus mobilisation and feasting by the 2nd millennium palaces. To date, however, faunal remains – the most widely available evidence for human use of animals – have been neglected: detailed reports of large assemblages are non-existent and faunal evidence features rarely in works of synthesis. This thesis undertakes a diachronic study of a large faunal assemblage from Knossos – the largest and longest-lived site on Crete.

The faunal assemblage derives from different excavations and areas, enforcing careful evaluation of retrieval, modification by previous analysts, survival and, where archaeological information permits, contextual variation in discard behaviour. Attrition is lower in built-up than open areas through the 7th-3rd millennia, and very low in the suggested 'public/elite' core area of 2nd millennium Knossos. Butchery into big 'parcels' and subsequent dispersal of bones in the former period suggests reciprocal sharing, while intensive butchery and structured deposition in the latter suggest assymetrical feasts emphasising distribution of meat to participants. Butchery evidence also indicates rapid, wholesale adoption of metal in the 3rd millennium.

Feral populations of pigs and perhaps goats may have caused introductions of deer to fail. Domesticates, predominant throughout, were managed for diverse products in the 7th-4th millennia, including traction with cows. Increased adult and male survivorship in the 3rd millennium indicates potential specialisation in traction, wool and hair, but persistence of this pattern in the 2nd millennium 'public/elite core' also suggests demand for impressively large carcasses.

Results of broad significance include reciprocal sharing, early traction with cows, rapid adoption of metal and linkage between feasting and secondary products management.

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LIST OF ABBREVIATIONS

CHRONOLOGICAL TERMS	
EN	Early Neolithic
MN	Middle Neolithic
LN	Late Neolithic
FN	Final Neolithic
EM	Early Minoan
MM	Middle Minoan
LM	Late Minoan
OP	Old Palace
NP	Neopalatial
FP	Final Palatial
BA	Bronze Age
EBA	Early Bronze Age
MBA	Middle Bronze Age
LBA	Late Bronze Age
ZOOARCAHEOLOGICAL TERMS	
AEC	Anatomically Expected Count
MaxAU	Maximum Anatomical Units
MDT	Major Domestic Taxa
MinAU	Minimum Anatomical Unit
NISP	Number of Identified Specimens
HC	Horncore
MD	Mandible
SC	Scapula
Hp	Humerus proximal
Hd	Humerus distal
Rp	Radius proximal
Rd	Radius distal
U	Ulna proximal (olecranon)
MCp	Metacarpal proximal
MCd	Metacarpal distal
PE	Pelvis
Fp	Femur proximal
Fd	Femur distal
Tp	Tibia proximal
Td	Tibia distal
A	Astragalus
C	Calcaneum
MTp	Metatarsal proximal
MTd	Metatarsal distal
MPp	Metapodial proximal
MPd	Metapodial distal
PH1-3	Phalanges 1-3

KNOSSOS: EXCAVATED AREAS	
CC	Central Court
WC	West Court
RR	Royal Road
RRN	Royal Road North
RRS	Royal Road South
PEM	Palace Early Minoan
EH93	Early Houses 1993
RT	Road Trials
HH	Hogarth's Houses
PW	Palace Well
WCH	West Court House
AQW	Aqueduct Well
MUM	Unexplored Mansion
Evans1	J.D. Evans 1957-60 campaign
Evans2	J.D. Evans 1969-70 campaign
BIBLIOGRAPHIC ABBREVIATIONS	
AR	*Archaeological Reports*
KS	*Knossos Survey - Hood and Smyth 1981*
KP	*Knossos Palace - Hood and Taylor 1981*
PM	*Palace of Minos*
RAP	*Review of Aegean Prehistory*

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1 INTRODUCTION

1.1 Introduction

As is the case with almost any pre-modern society, animals would have played a major role in all aspects of prehistoric Cretan culture, as providers of food, raw materials and traction and, concomitantly, as socio-economic and symbolic resources. The study of animal remains has contributed minimally, however, to the understanding of Neolithic and Bronze Age societies on the island. Using the results of zooarchaeological analysis of animal bone groups from Neolithic and Bronze Age contexts at Knossos, a site which developed over six millennia from early Neolithic farming colony to Bronze Age palatial and urban centre, the present study attempts to elucidate some aspects of Cretan prehistory, relating to the human consumption and management of animals.

This introductory chapter begins with a brief discussion of the paradigms, research questions and methods which have shaped Cretan prehistoric archaeology, from the pioneering work of Sir Arthur Evans to the present, in relation to their impact on the practice and character of archaeological and, more specifically, zooarchaeological investigations on Crete over the 20th century. It continues with a summary of questions, old and new, which zooarchaeological evidence, in particular evidence deriving from Knossian assemblages, could help to clarify, and concludes with an outline of the structure of the thesis.

1.2 The nature of archaeological investigations on Crete

1.2.1 Beginnings: Sir Arthur Evans

Sir Arthur Evans, son of a wealthy industrialist, was educated in the classical tradition, like the majority of his contemporaries of sufficient means. All early practitioners of archaeology in Greece shared this education, a wider western European phenomenon in the 19th and early 20th century firmly rooted in the study of ancient texts. Evans, however, did not share the research incentive of Schliemann to prove the historicity of the Homeric epics (MacGillivray 2000: 64-5). His original interest and subsequent archaeological explorations on Crete stemmed from his fascination with the history of languages and writing. Evans' investigations were initially prompted by a seal brought to the Ashmolean Museum. This he recognised as being inscribed

with a, then unknown, writing system, which he eventually traced to Crete (A. Evans[1] 1894; 1935: 667 and notes 1-3). On the other hand, Evans' idea of archaeology was certainly formed under the influence of his father's – and before that his grandfather's – scholarly pursuits and connections. Both his grandfather, Arthur, and his father, John Evans, were keen collectors and scholars; the latter in fact served as a senior member of several learned societies[2] and was particularly interested in the study of geology (J. Evans 1943: 155-57.).

Taxonomic and typological pursuits, which were an integral part of collecting, and evolutionist ideas, transposed from geology and zoology to artefacts and human societies, formed the core of Evans' intellectual baggage (MacNeal 1974; Cherry 1983). This pedigree is informative for understanding Evans' interpretation of Minoan material culture and society and the ultimate affinity of Minoan to Classical archaeology, another discipline firmly rooted in 18th century 'antiquarianism and connoisseurship' (Bennet 2002: 219).

Once on the island, Evans was drawn to the site of Knossos partly due to the discoveries of Minos Kalokairinos, a wealthy Cretan merchant and amateur archaeologist who had conducted small-scale investigations towards the end of the 19th century at the Kephala tou Tselevi – as the site of the palace at Knossos was then known to the locals (Kopaka 1995). Evans' own investigations at Knossos began in 1900 and concentrated on Bronze Age remains, but Neolithic strata were also excavated in the West Court of the palace (A. Evans 1921: 34). Excavation was rather rapid by today's standards: in 1904 the 'wager method' was introduced to speed up removal of what were thought to be post-Minoan deposits, on the basis of changes in soil colour and consistency which were, however, not always reliable (Hatzaki pers.comm.). Considerable effort was expended by Evans' field director, Duncan Mackenzie, in ensuring adequate recording and excavation methods – insofar as was possible with the available means and given that a single archaeologist had to oversee the work of several dozens of workmen (Momigliano 1999). There is, however, no evidence that any systematic effort was made to collect bioarchaeological material: only one assemblage has ever been located, a small group of bones and seeds from the Temple Repositories and West Pillar Crypt (Panagiotaki 1999) and occasionally the odd bone is now found in pottery boxes at the Stratigraphical Museum at Knossos. There is no mention in the *Palace of Minos* of any bioarchaeological study, other than references to finds of charred grain identified by workmen.

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[1] Because three scholars are referred to in the present study, all named Evans, the convention adopted for references, only in their case, is for their surname to be preceded by their initials. Thus, Arthur Evans is A. Evans, Joan Evans is J. Evans and John Evans -- the excavator of Neolithic Knossos – is J.D. Evans.

[2] For example John Evans served as Secretary of the Numismatic Society, was President of the Geological Society and Vice-President of the Society of Antiquaries in the last decades of the 19th century (J. Evans 1943: 166-7).

Over three decades, Evans' excavations on the Kephala hill revealed a large architectural complex with monumental features, wall paintings, written documents, and vast quantities of elaborate artefacts – often employing exotic materials. The building complex was identified by Evans as the residence of the elite of a sophisticated culture. Through the study of stratigraphy (A. Evans 1921: 28) and pottery, a cultural sequence was developed for the whole of the Minoan period, as Evans did not limit himself to the excavation of the palace of Knossos. He investigated a number of cult sites – caves and peak sanctuaries – burial sites, and what he believed to be elite countryside residences, dubbed Minoan *villas*. Absolute dates for this sequence were derived from parallels with Egypt (A. Evans 1921: 31), since ^{14}C dating was not available at the time.

Evans presented the results of his archaeological pursuits on Crete in a series of volumes entitled *The Palace of Minos* (henceforth *PM*) published between 1921 and 1935. Information on the excavations was based on Mackenzie's detailed daybooks (Momigliano 1999: 40-5), a systematic and incisive field archaeologist at a time when excavation methodology was being invented on the spot (Momigliano 1999: 25). Throughout the four volumes, selected finds and architectural features are described and discussed in the context of specific themes: written records, religion and ritual, arts and crafts, external relations and trade. Trade connections with the Near East and Egypt and their purported ideological influences on Minoan culture are central to Evans' discussions, based on extensive comparative analysis of the material culture of these areas and of Minoan Crete, but also to a great extent on conjecture.

PM is far from what would be considered today as the full publication of an excavation, nor was it indeed conceived as such by its author (Boardman 1963: 4); it constitutes, rather, a lengthy treatise in which Evans presents his 'vision of Minoan society' (Bennet 2002: 214). While the choice of topics (elite art and architecture, religion) and his treatment of the evidence are very much within the tradition of classical archaeology, his interpretations of society and change, even in terms of pottery styles, were heavily influenced by ideas of social evolution adopted and adapted from biology (MacNeal 1974). A reader interested in other aspects of the past – especially what is commonly referred to in *PM* as 'everyday life' and presumably encompassing agriculture, animal management, food, etc. – and bodies of material other than fine pottery, frescoes and elaborate artefacts, is confronted with an almost total lack of reference. Of importance to the present study are the contexts in which animals are mentioned: in relation to Linear B documents (A. Evans 1935: 722-4) and iconographic representations, either in wall paintings or as zoomorphic artefacts (e.g., A. Evans 1921: 44, 120, 153, 272, 510-5, 541; 1935: 9-11).

Discussions of texts are mostly descriptive, though incisive, given that Linear B was not deciphered until the 1950s: ideograms are attributed to specific animals, while the groups of animals listed in the tablets are recognised as 'flocks and herds' (A. Evans 1935: 722-5). Iconography mainly prompts discussions concerning religion and ritual (A. Evans 1928: 324, 764; 1935: 498), with 'bull fighting', 'bull grappling' (e.g., A. Evans 1921: 189-90, 1930: 177-91) and sacrifice (e.g., A. Evans 1928: 408) the recurrent themes. References to the exploitation of primary and secondary animal products are exceptionally rare: the possible use of oxen and asses as pack and draught animals[3] (A. Evans 1921: 224; 1928: 156-7; 1935: 83), of *agrimi* (feral goat) horns for the manufacture of composite bows (A. Evans 1935: 833-5), and of hunted boars' tusks for the manufacture of helmets (A. Evans 1935: 869).

Physical remains of animals are discussed only once: fragmentary skulls of cattle with attached horncores discovered in the vicinity of tripod altars (objects commonly interpreted as cultic equipment) inside a room named (significantly) the 'House of the Sacrificed Oxen'. The whole group is interpreted as 'sacrificial relics' representing 'a solemn expiatory offering to the Powers below' to avert earthquakes (A. Evans 1928: 302, fig. 175).

The validity of the views proffered by Evans in regard to the role of animals in the Minoan symbolic universe will be discussed below, but what is important to stress here is the narrowness of Evans' interest in animals, largely limited to ritual and religion. This narrow focus, and the perceived marginal role of faunal remains in illuminating the subjects of interest to Evans, perhaps account for the failure to systematically recover animal bones during excavation (for an exception see section 1.3.2).

1.2.2 After Evans: bones vs. pots and images

Arguably, because of the research agenda set out by Evans, especially the stress put on relations with Egypt and the Near East, artefact studies acquired a supreme role, as evidence for trade, craft specialisation and dating, not least in providing synchronisms with the areas whose influence was purportedly instrumental in the rise of civilisation on Crete (Cherry 1984: 21; Driessen 1990: 5). As regards pottery in particular, the variety of shapes and decoration and the rapid change of styles were recognised already by Evans as a powerful tool for constructing typological sequences (A. Evans 1906). These helped to create fine chronologies, in the pre-^{14}C era, and, even now, the distinctions possible can provide finer dating than ^{14}C for some periods.

[3] The underlying theme seems to be trade of artefacts.

Unfortunately, for several researchers, typological analysis of pottery has been an end in itself, at the expense of other approaches and bodies of material, such as bioarchaeological remains.

By the mid-20th century, the dominant attempt at explaining the rise and development of 'Minoan Civilisation' was that set out by Childe. According to his diffusionist model, Minoan palatial civilisation arose, following contact with its Near Eastern and Egyptian counterparts, as a result of the adoption of new technologies (metallurgy) and accumulation of wealth by Cretan rulers from a monopoly of overseas trade (Childe 1957: 151). This was reflected in a number of apparently imported artefacts and iconographic themes, borrowed from the Near East and Egypt, and by purported parallels in palatial architecture, writing and sealing systems. Such ideas, latent in the work of Arthur Evans and his successors, but never overtly stated (Cherry 1984: 20), reinforced the emphasis within Minoan archaeology on the study of fine pottery and other prestige artefacts.

Analysis of faunal remains, although not unheard of in other parts of the world, was at an embryonic stage in the first half of the 20th century on Crete; Evans' attitude was not exceptional. Hatzidakis and Marinatos report on analysis by zoologists of finds from Tylissos (Hatzidakis 1921: 76) and Krasi (Marinatos 1929), but these are rare exceptions, and the discussions are very brief and not very informative, being mostly species lists. In the absence of adequate methods, archaeologists were still unable to realise the potential of faunal analysis for addressing archaeological questions.

The art-historical approach is manifest in the reliance on text and iconography for providing seemingly easier and more reliable answers about the past. The following passage in Pendlebury's *The Archaeology of Crete* is revealing: 'The lack of interest on the part of the Minoan artist in *everyday life* at home and in the fields has deprived us of a great source of knowledge. Sheep and goats were kept, as well as oxen. *We know that from the bones*. But what were the draught animals?' (Pendlebury 1939: 270, emphasis added). Given that, so far as we know, no animal bones were kept from any of the excavations conducted by Pendlebury, and no discussion of bones appears in any of his excavation reports, one assumes that the identification of the bones was made during excavation. Evidently, Pendlebury recognised both the importance of what he called 'everyday life' and the usefulness of animal remains in illuminating this aspect of Minoan culture, but he considered iconography the richest and most reliable source of evidence. This betrays the commonly shared belief that Minoan iconography provided faithful representations of nature: the Minoan artist's 'observation of nature is brought out in the almost *photographic* representations of animal life' (Pendlebury 1939: 276, emphasis added; see also Masseti 2003a; Vanschoonwinkel 1996).

As late as 1971 published zooarchaeological studies for Crete were so rare that hardly any results were available for reporting in Hood's survey of the Cretan Bronze Age, *The Minoans* (Hood 1971). This book is primarily addressed to the interested amateur and undergraduate and has no pretensions to being an exhaustive account of Cretan prehistory, but the lack of information from faunal analyses is evident when relevant topics are discussed. The introduction of domesticates to Crete by Neolithic settlers is touched upon (Hood 1971: 22)[4], as is the use of animals as providers of primary and secondary products. For the Bronze Age, on the other hand, discussion is based on iconographic and textual evidence in a manner reminiscent of Arthur Evans and Pendlebury, while several assumptions are made based on common sense rather than zooarchaeological or other relevant evidence. Here too iconography is taken at face value: the supposedly naturalistic rendering of some animals suggests to the author that lions are likely to have existed on the island (Hood 1971: 222). Such a statement is not surprising in the early 1970s, given that contradictory palaeontological evidence and models of island biogeography and ecology were first introduced into Aegean archaeology about a decade later (Cherry 1981). Significantly, however, as excavator of Bronze Age levels at Knossos from the late 1950s onwards, Hood systematically collected faunal remains, and had the material analysed by zooarchaeologists.

1.2.3 New Archaeology and beyond

1.2.3.1 *Zooarchaeologists at last! Crete and the Early History of Agriculture Project*

Zooarchaeological studies, in the current sense of the word, begin in the late 1960s with the analysis by Michael and Heather Jarman of faunal remains from excavations by Hood and J.D. Evans. The study of the material from the latter's excavations of Neolithic levels at Knossos was undertaken as part of the British Academy Major Research Project on the Early History of Agriculture under the general direction of Eric Higgs (Jarman and Jarman 1968: 241; Winder 1991). Higgs and his team were proponents of Economic Archaeology and were at the forefront of bioarchaeological research at the time, in terms of both theoretical and methodological approaches. Their analytical methods were explicitly designed for analysing archaeological remains and addressing archaeological questions. Higgs and Jarman cited archaeobotanical and zooarchaeological evidence from the earliest levels at Knossos in a critique of the traditional model of agricultural origins in a restricted Near Eastern 'hearth', from which a 'package' of crop and livestock species was carried to Europe (Higgs and Jarman 1969).

[4] Hood reports on the findings of Jarman at Knossos from J.D. Evans' excavations.

During the same period, M. Jarman was invited to study the material from two other projects on Crete, the EM sites of Debla (directed by Y. Tzedakis and P. Warren) and Myrtos-*Phournou Koryphi* (directed by P. Warren). The issues addressed (animal management, palaeoeconomy, the consumption of animal products, etc.), and the reliance on results of faunal analysis by *zooarchaeologists*, distinguish these studies from earlier and later ones undertaken by *non-zooarchaeologists,* as was the case with the Tylissos and Krasi studies mentioned above.

The results of the Jarmans' study at Knossos, however, were not published, with the exception of a single article discussing only a fraction of the Neolithic assemblage, the Aceramic and part of the EN material from the first campaign (Jarman and Jarman 1968). In fact, many of the zooarchaeological studies undertaken by the Early History of Agriculture Project were abandoned unpublished for various reasons discussed by Winder (1986: 28, 76; 1991: 20-1). Analyses by the Jarmans for Debla (Warren and Tzedakis 1974) and Myrtos-*Phournou Koryphi* (Jarman 1972) were published, but the assemblages were too small to support the conclusions drawn by the specialists and excavators alike. As a result, they have been used only marginally in synthetic studies, often to draw conclusions poorly if at all supported by the data themselves (e.g., Cherry 1988; Watrous 2001). The much larger and thus more significant assemblages from Knossos were never fully published.

1.2.3.2 *Renfrew and the 'Subsistence Sub-System'*

The Jarmans' analyses, informed by then novel theoretical and methodological approaches, were not an isolated phenomenon in Aegean archaeology. At around the same time, Renfrew's *Emergence of Civilisation* appeared (Renfrew 1972), which has had a major impact in the field, still evident today (e.g., see various reviews in Barrett and Halstead *in press*). Its importance lay in the fact that for the first time an *explicitly* theoretical framework was applied to the explanation of social change in prehistoric Aegean societies. Renfrew's approach was firmly rooted in the processual paradigm, which sought generalising explanations of the past, partly based on cross-cultural comparison, and borrowed ideas and models from fields such as human geography, ecology, and social anthropology.

In reaction to Childe's diffusionist model for the emergence of Aegean palatial civilisation, Renfrew made a case for an essentially indigenous development: 'positive feed-back' between various cultural sub-systems – the subsistence, technological, social, projective/symbolic and trade/communication sub-systems (Renfrew 1972: 22-3) – culminated in the rise of Middle Bronze Age palace-states in the Southern Aegean. Central to his argument was the advent of

new crops, the vine and olive, which together with grain formed the 'Mediterranean triad'. The exploitation of these new crops allowed the expansion of cultivation into marginal areas and production of agricultural surplus, while their cultivation by specialist farmers required managerial elites to pool and redistribute ('subsistence-redistribution model') their low bulk-high value products (wine and oil). In this way, the socio-economic structures which led to the rise of the Bronze Age palatial states on Crete were created.

Regardless of the validity of the specific models it advanced, the *Emergence* was crucial in that, apart from its explicit appeal to theory, it drew attention to aspects of the archaeological record which were previously neglected, i.e. bioarchaeological remains. At the same time, by drawing attention to agriculture and animal husbandry, it redefined the economy as more than the trade of luxury and exotic objects and materials. Renfrew's re-formulation of the Aegean research agenda was taken up subsequently by many researchers and, since 1972, studies of a more or less processualist nature have addressed a range of issues, including the relationship between humans and other animals in successive periods of Cretan prehistory.

1.2.3.3 *Early farmers on Crete*

For the Neolithic, a major area of discussion has been the initial human colonisation of the island and its impact on the Cretan 'natural' environment, in particular on any extant indigenous fauna. An extensive body of research by palaeontologists and palaeoecologists has discussed the Quaternary mammalian faunas of Mediterranean islands (see reviews by Cherry 1981; Schüle 1993; Vigne 1988; 1993; 1996; various papers in Reese 1996), while archaeologists have stressed the possible human impact on indigenous faunas. The impact of Neolithic human colonists on Crete was addressed by Lax and Strasser, who argued for human-induced extinction of the mammalian endemic fauna on Crete, caused by competition with humans and their domestic animals, following Diamond's *Sitzkrieg* model (Lax and Strasser 1992). A diachronic study of the Cretan mammalian fauna during the Holocene by Jarman, which circulated as an unpublished text for a long time before eventual publication (Jarman 1996), drew attention to the probable anthropogenic introduction of wild as well as domestic animals.

Such interest in animals from an ecological point of view is rare among prehistorians working on Crete. One exception is *The Making of the Cretan Landscape* (Rackham and Moody 1996) which investigates the development of the Cretan ecosystem in the Quaternary. Particular emphasis is given to anthropogenic changes, which the authors argue were instrumental in shaping the present state of the Cretan landscape. The approach adopted is of great importance

in showing how a combination of ecology, botany, palynology, palaeontology, ethnography, and recent historic documents can be used to address a number of palaeoecological issues relevant to archaeology. Zooarchaeological evidence features minimally in this study, however, the strengths of the authors being mainly the fields of botany/historical ecology and archaeology/geomorphology.

Models of animal island biogeography (e.g., MacArthur and Wilson 1967) were applied heuristically by Cherry to the investigation of the mechanisms and forms of island exploitation by human groups in the Aegean and Mediterranean. Cherry noted that, while colonisation of islands by other animals is heavily influenced by the length of sea crossings, human colonisation of Mediterranean islands appeared to be shaped primarily by the size and ecological diversity of islands, regardless of distance. The agricultural colonisation of the large island of Crete exemplified a pattern of selective island settlement, making use of boats or rafts (Cherry 1981; 1990). This approach was developed by Broodbank and Strasser (Broodbank 1999; 2000; Broodbank and Strasser 1991), who emphasised the purposive colonisation of Crete by early Neolithic farmers (Broodbank and Strasser 1991: 239). Starting from the premise that all domesticates archaeologically attested in the earliest levels at Knossos (sheep, goats, pigs and cattle) were introduced, they discussed the practical problems of transporting by sea sufficient numbers of animals to create reproductively viable flocks (Broodbank and Strasser 1991: 240). The successful colonisation of Crete by early farmers thus implied an organised 'expedition' rather than speculative seafaring. Vigne has adopted a related starting point in a series of recent papers comparing Early Neolithic faunas from island and mainland locations across the Mediterranean. Faunas rich in sheep and poor in wild mammals, such as that reported by the Jarmans from early levels at Knossos, are assigned to sea-born colonist farmers, while more mixed faunas are interpreted as representing the adoption of domesticates by indigenous populations (Vigne 2000: 160-1).

In a survey of bioarchaeological evidence from the Neolithic of Greece as a whole, Halstead (1981a) interpreted the sheep-dominated fauna of early levels at Knossos and at contemporary sites on mainland Greece in terms of small-scale mixed farming, in which domestic animals grazed and manured arable land. In a later article, Broodbank assessed the available artefactual and bioarchaeological evidence from the Aceramic to the Late Neolithic at Knossos, to conclude that an increase in the relative proportion of cattle from the Early to the Middle Neolithic could be related to a wider socio-economic transformation, associated with expansion of the Knossos settlement beyond the limits of egalitarian organisation (Broodbank 1992). This latter argument and a critical response by Whitelaw (1992) are reviewed at greater length below (Chapter 3).

Other studies have explored changing settlement patterns on Crete and in the wider Aegean, with particular emphasis on the expansion of human occupation into, and exploitation of, new ecological zones, characterised as 'agriculturally marginal', at the end of the Neolithic (late 4th to early 3rd millennium BC). It has been argued that expansion into such areas (mainly uplands, with the concomitant use of caves) was made possible by: a) the introduction of new crops (i.e. olive and vine) following Renfrew's model of 'Mediterranean polyculture'; and b) increased reliance on livestock for subsistence, in part facilitated by the introduction of new animal husbandry techniques, such as traction – including ploughing – milking/cheese making and wool production (e.g., van Andel and Runnels 1988). The latter follows Sherratt's model of a 'secondary products revolution' (Sherratt 1981), which ostensibly coincides chronologically with the expansion of settlement in marginal areas of the southern Aegean (Cherry 1988; Watrous 2001: 166).

In the case of Crete, such upland sites had been interpreted in terms of seasonal occupation by specialised pastoralists, independently of Sherratt's model and on the basis of site location (Watrous 1977; 1982). The purported importance of pastoralism and the existence of specialist herders have also been used to explain the establishment of peak sanctuaries in the vicinity of upland pastures in the late pre- and early Protopalatial periods (e.g., Rutkowski 1986) and the expansion of settlement into upland areas again at the end of the Bronze Age (e.g., Vickery 1936[5]). As Cherry and others (e.g., Cherry 1988; Halstead 1996b) have argued, however, such inferences, also common in earlier works (e.g., Warren and Tzedakis 1974), are not supported empirically and belong to a school of thought which envisages transhumant pastoralism as an 'environmentally-determined' adaptation to the Mediterranean landscape, rather than a response to historically contingent socio-economic conditions.

1.2.3.4 *State formation and palatial economy*

Following Renfrew's synthesis, a number of studies dealt with Aegean Bronze Age state formation from a processualist perspective. In Cherry's discussions of state formation (Cherry 1983; 1984), novel uses of animals in ploughing and as sources of milk and wool feature as prerequisites – although, as he stresses, not sufficient in themselves – for the development of palatial society (Cherry 1984: 26). Halstead argued that strategies deployed in order to cope with inter-annual variability in crop yields, and with resulting periodic food shortages, may have been manipulated by individuals aspiring to power (e.g., Halstead 1981b: 194). Apart from the direct storage of surplus crops in good years, other possible strategies suggested were: a) the *indirect* storage of crop surplus by feeding it to domesticates, especially sheep (Halstead 1981b:

[5] Vickery cites Kavousi as an example of a herding camp on the basis of its location – high in the hills (cited in Cherry 1988: 9).

195; 1993; 1994: 202); and b) *social storage*, that is the exchange of foodstuffs for 'durable valuable, non-food tokens', which in time of scarcity could be exchanged for food (Halstead 1981b; Halstead & O'Shea 1982). The latter was proposed as a mechanism by which individuals or groups accumulated wealth and subsequently power (Halstead & O'Shea 1982: 98). More relevant to the present thesis is the suggestion that manipulation of direct storage and indirect storage through livestock may have formed the basis for some activities of the later palatial centres (Halstead 1988: 524).

For the Late Bronze Age, decipherment of the Linear B script by Ventris in the 1950s (Chadwick 1958) provided invaluable insights into palatial economy and administration, both on Crete and southern mainland Greece. Most relevant for the present discussion is Killen's seminal study of the sheep and wool tablets from Knossos, the earliest written attestation in Europe of large-scale management of flocks for mass production of a secondary product (Killen 1964; 1993a) and the same author's discussion of the role of plough-oxen in palatial grain production (Killen 1993b; 1998). Halstead has drawn extensively on discussion of textual evidence by Killen and other Linear B scholars (e.g., Bennet 1988; Killen 1964; 1984; 1993a; 1993b; 1994; 1998; Olivier 1967; 1988; Palaima 1992), interpreted in the light of recent ethnographic observations of animal husbandry practices (e.g., Halstead 2003), to explore manipulation of animal management by the Middle and Late Bronze Age palatial elites. Of importance for the present study is his emphasis on the central role in palatial economy of sheep flocks managed for wool (Halstead 1995a; 1998-9; 2001) and of plough oxen (Halstead 1992d; 1995b; 1999). The opportunity to juxtapose evidence from the faunal and textual records, however, has been hampered by the paucity of zooarchaeological data (Halstead 1992b; 2003).

More recently, and possibly as a critical response to the processualist emphasis on land use and nutrition, a number of studies have emphasized the likely political importance of feasting financed by palatial elites. Moody has argued that, from the Protopalatial period, the agricultural surplus accumulated by the palace was 'redistributed to the masses by means of frequent and regular feasting' and that 'with the development of a stratified society, redistribution no longer functions as a social levelling device; it instead evolves into what has been called mobilisation' (Moody 1987b: 240). Some proponents of feasting have stressed the importance in this context of the consumption of wine (e.g., Hamilakis 1996b), as evidenced by the variety of often elaborate drinking and pouring vessels (Wilson and Day 2000; Wright 1996), while others have discussed Linear B evidence for the consumption of animals in ceremonial/religious contexts (e.g., Halstead 2003; Killen 1994). It has also been proposed that funerary feasts in Prepalatial contexts may represent the precursors of palatial feasting (Hamilakis 1998b: 119-29).

1.2.4 The present state of Cretan zooarchaeology

Animals and human exploitation of animals are prominent in a number of the recent debates summarised in the previous sections, and faunal evidence is crucial to resolving many rival arguments (Cherry 1988: 6-7). It is striking, however, that most of the models reviewed above are based either on zooarchaeological data from regions of the Aegean outside Crete or on other types of evidence (e.g., palaeontological finds, archaeological site locations). This reflects the fact that published zooarchaeological data (and indeed bioarchaeological data in general) are still extremely sparse for Crete: other than the tiny assemblages from Myrtos-*Phournou Koryphi* and Debla, and highly selective or preliminary reports from a handful of other sites, the faunal data presented in this thesis cannot be compared with any contemporary material from Crete.

The paucity of published faunal studies is well illustrated by three recent surveys of relevant subjects. The edited volume, *Pleistocene and Holocene Fauna of Crete and its First Settlers* (Reese 1996), is useful in that it brings to the attention of archaeologists work on the Pleistocene fauna, mainly undertaken by palaeontologists. On the other hand, it illustrates the limited range of zooarchaeological research undertaken on Crete: other than Jarman's review (originally written in the early 1970s) of evidence for human impact on the Holocene mammalian fauna of the island, discussion of new zooarchaeological evidence is restricted to three brief reports on excavated material from LN to Byzantine contexts (by Wilkens, Tsoukala and Walker) and a study of badger as a food resource at the end of the Bronze Age (by Snyder and Klippel).

The edited volume entitled *From Minoan Farmers to Roman Traders* (Chaniotis 1999), contrary to what one might expect from the title, does not include a single article discussing issues arising from the analysis of bioarchaeological data. The only article dealing with 'farming' is Nowicki's study of settlement patterns after the collapse of the Palaces at the end of the Bronze Age. In the absence of bioarchaeological evidence, the economic/subsistence basis of 'refugee settlements' is reconstructed by analogy with recent ethnographically observed practices in the Lasithi plateau (Nowicki 1999).

The 2001 compilation of seven articles on different periods of Aegean prehistory (henceforth RAP I-VII), which originally appeared over the 1990s in the *American Journal of Archaeology*, reviews recent discoveries and current debates within the field and provides insights into the current state of bioarchaeological research and its reception by non-specialists. RAP III (Watrous 2001) & VII (Rehak & Younger 2001) deal specifically with Cretan prehistory. Watrous reviews the Neolithic to the First Palace periods, and Rehak and Younger the New and Final Palace periods. Watrous' review pays more attention than is customary to issues of animal management but also highlights the paucity of information from published faunal analyses. He

argues that the (bio-archaeologically unproven) secondary products revolution, with concomitant increased reliance on animal produce and pastoralism, was the decisive factor enabling the expansion of settlement in marginal areas of Crete at the transition from the Final Neolithic to the Early Bronze Age. In the absence of bioarchaeological information, other than the tiny assemblages from EMI Debla, he resorts to settlement size and location as supporting evidence (Watrous 2001: 166).

There are several reasons for the scarcity of zooarchaeological data from Crete. One problem is the poor publication record of faunal analyses. Although faunal material at least has been collected quite systematically since the 1950s at Knossos and subsequently at other sites, published zooarchaeological reports are few and are either of a preliminary character (e.g., Jarman and Jarman 1968, Tsoukala 1996; Wilkens 1996a; 1996b) or sufficiently incomplete in their presentation of data and/or methods of analysis as to be of limited utility (e.g., Bedwin 1984; Reese 1995a; 1995b).

The inadequacy of some publications is due to their execution by specialists with non-archaeological backgrounds (zoologists and palaeontologists in particular). Such scholars are often unaware of the array of methods now available for the analysis of *archaeological* faunal assemblages (e.g., Nobis 1988; 1989; 1990; 1993; Persson 1993; Tsoukala 1996) and, understandably, use methods applicable to their own disciplines, but not necessarily relevant to zooarchaeological analysis. Above all, the failure to address archaeologically relevant questions results in reports of limited value to archaeologists. The root problem here is the common misconception among *archaeologists* that bioarchaeology is best practised by specialists from other fields. Indeed some archaeologists are unaware of the content and methods, or even existence, of zooarchaeology. The following passage is revealing: 'This long overdue development [study of land-use and the basis of the economy] has been aided by an increasingly systematic use of the sciences, especially *geology, botany and zoology*, to investigate the modern landscape and natural settings of sites as well as the remains from them' (Dickinson 1994: 5, emphasis added).

Another fundamental problem has been that, at least until the late 1970s, faunal remains were not collected in excavations as a matter of course, while *systematic* bioarchaeological investigations (including intensive sampling), even in the context of research-driven projects, have been undertaken only in the last 10-15 years. In the case of rescue excavations by the Greek Archaeological Service, constraints of time, funding and specialist skills mean that, normally, only bone and the occasional charred olive pip are recovered in the trench during excavation. Even in research excavations (Greek and foreign), however, hand recovery is the

norm, resulting in incomplete and biased faunal assemblages (Payne 1972). Bioarchaeologists are very rarely invited to participate in designing excavation and sampling strategies prior to the start of a project. Rather, specialists are brought in to analyse material on a *post hoc* basis, after an excavation has been completed or is well under way, or when excavation reveals something that appears extraordinary to the excavator. Watrous presents a rosy picture of systematic bioarchaeological research on Crete (Watrous 2001: 160). He is closer to reality, however, in commenting that: 'It is disturbing that while such economic questions [the role of fishing and the beginnings of olive cultivation] are being actively discussed in the literature, many current well-financed foreign excavations in Crete are failing to watersieve' (Watrous 2001: 213). Bioarchaeological investigations are perceived by many project directors as too expensive for the quality of information they provide. They are often undertaken half-heartedly, out of necessity rather than conviction (e.g., when prescribed by funding bodies such as the Institute for Aegean Prehistory), or even not at all.

Why have Minoan archaeologists been so reluctant to invest in bioarchaeological studies? Plainly, the lack of published data and, more particularly of data relevant to archaeological questions, has not encouraged such investment. On the other hand, the lack of interest in bioarchaeology is also related to the research agendas of Minoan archaeologists. Significantly, those scholars who have discussed the role of animal exploitation in Cretan prehistory have either not directed fieldwork on Crete (e.g., Renfrew, Cherry, Halstead) or have directed survey rather than excavation projects (e.g., Moody, Watrous). The archaeology of the Aegean has been traditionally taught in North American and European (indeed until recently in most British) universities in Classics or Classical Archaeology departments, where the prevalent cultural-historical approach, with a strongly philological and art-historical bias, has meant that new paradigms and, for the most part, field methods have been very slowly adopted (Renfrew 1980; Snodgrass 1985).

The lack of integration of zooarchaeological analysis into mainstream Aegean research is illustrated by some recent publications. The volume, *Pleistocene and Holocene Fauna of Crete and its First Settlers* (Reese 1996), in addition to the palaeontological and zooarchaeological contributions discussed above, includes several papers (by Vanschoonwinkel, Karali, Porter and Guest-Papamanoli) dealing, in some cases uncritically, with animals in iconography.

RAP VII, the review by Rehak and Younger of New and Final Palatial Crete, in contrast with Watrous' treatment of preceding periods, ignores animals. Of interest is the authors' concluding 'wish list' of areas to be targeted by future research. Rehak and Younger note that 'the lived life of individuals [presumably including agro-pastoral activities, eating, cooking, etc.] has all but

been neglected' (Rehak & Younger 1998: 464-5). Given this concern and the paucity of available bioarchaeological data, it is surprising that more, and more systematic, bioarchaeological investigations are not highlighted as a priority for future research. It seems that the later the period under consideration and the more sophisticated the material culture, the less relevant bioarchaeological evidence and related issues become to Cretan prehistorians.

In Dickinson's *The Aegean Bronze Age* (Dickinson 1994), animal husbandry is mainly discussed in terms of the secondary products revolution, with mention of sites where faunal remains are reported to suggest intensification for secondary products. The discussion, however, focuses on information provided by the Late Bronze Age Linear B documents. The introduction of equids is discussed, and also the importance of hunting, in particular of wild boar, but significantly in connection with an artefact: the 'boar's tusk helmet'.

The edited volume *Minoans and Mycenaeans: Flavours of their Time* does place emphasis on animals as providers of food, investigated in this case mainly through chemical analysis of residues extracted from pottery vessels and isotopic analysis of human skeletal remains (Tzedakis and Martlew 1999). Sections on zooarchaeological and archaeobotanical analysis are interspersed throughout the volume, but significantly the introduction omits any reference to them as part of the programme of investigation. The authors claim that the 'scientific' analytical methods (residue and isotopic analysis) used 'allowed the Minoan/Mycenaean civilisation to come alive in a way that was not possible before' (Tzedakis and Martlew 1999: 23). Plainly, both food residue and isotopic analyses are of great value, but neither is free of methodological problems and both are rather expensive for the quality of information they provide, which is essentially that of presence/absence. For example, the purported discovery of chemical signatures of meat and pulses in cooking pots may shed some light on methods of food preparation, but contributes nothing to our knowledge of Minoan diet which was not already known, more cheaply and with greater precision, from conventional macroscopic analysis of the, albeit, scanty bioarchaeological data. This volume is worrying in its enthusiasm for embarking on costly analyses with sometimes questionable outcomes, while ignoring more easily collected and more cheaply analysed faunal and botanical remains, which, for the time being at least, are arguably more likely to produce sophisticated results.

Whether responsibility for the present state of Cretan zooarchaeology is laid at the door of traditionally trained Minoan archaeologists or of faunal specialists (or, perhaps more realistically, of both parties), progress plainly demands the publication of more and higher-quality data and the demonstration that such data can address problems of archaeological significance. This thesis attempts to meet both of these requirements, by completing analysis

and interpretation of the large faunal assemblage available from Neolithic and Bronze Age Knossos.

1.3 The potential of zooarchaeological research at Knossos

1.3.1 The importance of Knossos

Knossos offers considerable potential for zooarchaeological research because of its long and complex history[6]. The six millennia long, uninterrupted occupation of Knossos through the Neolithic and Bronze Age allows a diachronic study of animal management and consumption. Moreover, over this timespan, the site changes dramatically in terms of size and function.

The earlier phases of the Neolithic, during which we see the development of a small farming colony, offer the opportunity to explore consumption and management by a more or less self-contained egalitarian community. In the later part of the Neolithic, as Knossos grows in size beyond the critical threshold for egalitarian organisation and becomes part of a denser network of settlements, questions of equality of access to animal products, at both the intra- and inter-community level, become increasingly important.

Increased external contacts and innovations, like metallurgy and the purported, though archaeologically evasive, use of the plough, may be linked to the rise of social ranking in the EM. In EMIIA Knossos, the central part of the site is possibly re-arranged and larger buildings appear, while new shapes and decorative schemes in pottery suggest an increased importance for conspicuous consumption of drink (and so perhaps of meat) in a communal context. In MMIB, the first palace is built at Knossos by an authority capable of mobilising the labour, materials, and technological know-how needed for large-scale monumental building. From this period onwards, the existence of hierarchy within and between sites becomes blatantly obvious. By the New Palace period, Knossos has grown into a large settlement with an estimated population of 14-18,000 inhabitants, while the palace houses record-keepers who monitor production and consumption of a range of resources, including animals, on a regional scale. Such developments raise questions about the use of space within Knossos (including the disposal of refuse such as animal bones), about access to animal products and pasture, about possible centralised distribution or processing of animal carcasses, etc.. Moreover, the palatial elites appear to have been heavily involved in ritual and ceremonial activities, including feasting.

[6] The history of the site of Knossos is considered in more detail in Chapter 3.

1.3.2 Previous faunal studies at Knossos and the need for re-analysis

As mentioned above, analysis of all the faunal remains from Knossos available by the early 1970s was undertaken by M. Jarman, but results have been reported (Jarman and Jarman 1968) only from the following contexts excavated during the 1957-60 campaigns of J.D. Evans:

- The Aceramic Neolithic assemblages;
- A sample of the ENI and ENII assemblages.

Jarman's synthetic study, written in the late 1970s but only published in 1996, provides very limited information about the later assemblages other than a table of the taxa identified by period; all the Bronze Age is lumped in a single column as 'Minoan' (Jarman 1996: 212, table 18.1).

In the 1980s, Winder undertook a re-analysis of the data collected by Jarman for the Neolithic period for the purposes of a doctoral thesis. His original aim, which was to re-study the assemblages themselves, was not realised and, as far as the faunal material itself was concerned, he undertook instead a statistical assessment of the Jarman data. Based on this he concluded that *all* the Neolithic assemblages were affected by taphonomic processes to a degree that rendered them unusable for investigating human behaviour (Winder 1986). Chapter 5 reviews Winder's study in the light of renewed study of the assemblages themselves. It is argued that, for methodological reasons, the Jarman data cannot be used to address the questions posed by Winder and that Winder's conclusions are open to debate.

Since Jarman's work at Knossos, only three prehistoric faunal assemblages have been published from the site: the Acropolis Houses (Jones 1979), the Minoan Unexplored Mansion (Bedwin 1984) and the Neolithic Throne Room system (Rushe and Halstead 1995), while a brief discussion of bone remains from the Temple Repositories and West Pillar Crypt are included in Panagiotaki's 1999 study, perhaps the only extant faunal assemblage from A. Evans' excavations at the site (Panagiotaki 1999). The first, third and fourth reports are based on very small assemblages, while the second is an extremely brief account of the findings.

As far as the materials studied by Jarman are concerned, the time that has elapsed between the original analysis and the present study means that, other problems aside, the data collected are obsolete as more and better methods are available nowadays in almost every aspect of analysis: e.g., taxonomic identification (sheep vs. goat), ageing and sexing, quantification, butchery mark interpretation. In addition, more powerful computing tools are now available to process

collected data (cf. Winder 1994 on the problems encountered by the Early Agriculture Project in the computerised analysis of data).

Given that the data published from Knossos to date are too few and too limited for sophisticated analysis, a contextualised re-analysis of the faunal material originally studied by the Jarmans, based on up-to-date zooarchaeological methods, was considered essential. This in combination with developments in other areas of knowledge (e.g., island biogeography, palaeontology, iconography, texts) is hoped to provide some answers to the questions posed in the past, depending on the size, nature and state of preservation of the available assemblages.

1.3.3 Research questions

The previous sections have highlighted five principal areas of debate as regards the role of animals in human societies of the Neolithic and Bronze Age on Crete:

- Agricultural colonisation and anthropogenic impact on the Cretan mammalian fauna;
- The role of practical and symbolic consumption of animals in social change at Knossos during the course of the Neolithic;
- The role of secondary products exploitation and pastoralism in changing settlement patterns at the end of the Neolithic and of the Bronze Age and in the location of peak sanctuaries;
- The role of animal management and consumption in the development and financing of Minoan palatial society;
- The role of animals in religion and ritual as reflected in iconographic representations.

Renewed zooarchaeological research at Knossos can contribute to each of these areas in the following ways:

Agricultural colonisation and the Cretan mammalian fauna: As a large diachronic assemblage, the faunal remains from Knossos can provide important material evidence for the dates of introduction to Crete of animal taxa. Since Jarman's survey of this issue, written in the early 1970s, there have been major advances in the availability of published criteria for distinguishing between taxa (e.g., red deer vs. fallow deer, sheep vs. goat), while the routine recording of variables related to taphonomic history may clarify whether burrowing animals (e.g., badger) have intruded into early archaeological levels. Faunal material from the earliest levels at Knossos may clarify whether early farmers on Crete had access to the full 'package' of domestic animals, an issue which has resurfaced in recent debate on the transition to farming in

Europe (e.g., Thomas 1999). In assessing diachronic evidence from Knossos for the introduction of 'wild' mammals, consideration will be given to contexts of discovery, in the hope of clarifying the socio-economic importance of deliberate introductions (e.g., fallow deer), and also to the possibility that introduced species may have competed with populations of feral domesticates occupying overlapping ecological niches.

Consumption of animals and Neolithic social change: Full analysis of the large diachronic assemblage from Knossos, coupled with recording of variables related to taphonomic history, may resolve whether the increase in the proportion of cattle during the course of the Neolithic is real, as argued by Broodbank (1992) following Jarman, or an artefact of taphonomic processes, as argued by Whitelaw (1992) following Winder (1986). Analysis of mortality data for the commonest taxa may also clarify whether any real increase in cattle among *deadstock* represented an increased proportion of *livestock*. More generally, following recent discussion of the role of food consumption in shaping social relations within Aegean Neolithic communities (e.g., Hourmouziadis 1979; Halstead 1995c), the social scale of consumption of animal carcasses at Neolithic Knossos will be explored through analysis of evidence of butchery and through consideration of the relative sizes of the carcasses consumed.

Secondary products exploitation and pastoralism: Evidence for, at least, *potential* management for secondary products at Knossos will be sought in the analysis of mortality and pathology data for the relevant common domesticates (cattle, sheep, goats). Such evidence may, in turn, suggest that specialised pastoralism is more or less plausible – again for animals consumed at Knossos. The Knossos assemblage is unlikely to shed direct light on marginal settlement in other parts of the island, although mortality evidence might theoretically suggest that animals were missing from Knossos in certain seasons or that the animals deposited at Knossos represent only part of a viable population.

Animal management and consumption in palatial society: The management of animals, at least of those disposed of in central areas of palatial Knossos, may be investigated by analysis of evidence for the relative abundance of different taxa and for patterns of mortality or pathology. Arguments for palatial specialisation, for example in wool sheep and plough oxen as previously suggested, may be supported by comparison with faunal evidence from Neolithic and Prepalatial Knossos, but must ultimately be tested by comparison with faunal evidence of Palatial date both from more peripheral areas of Knossos itself and from other sites. For similar reasons, it will be instructive to compare faunal evidence of Final Palatial date, both from central Knossos and from future excavations in more peripheral areas/other sites, with that of Linear B animal texts. Discrepancies between the textual and faunal records, with due account

for the taphonomic filters to which the latter is subjected, may help to expose the selective nature of Linear B records and so of palatial interest in animal husbandry.

Textual evidence indicates that feasting, including the consumption of meat, played an important role in Final Palatial strategies of legitimisation and mobilisation, while ceramic evidence suggests a similar role, at least for drink, in Prepalatial and earlier Palatial contexts. Faunal remains may offer diachronic insight into the importance of feasting on meat (*inter alia*, revealing whether Palatial 'feasting' marks a real departure from Neolithic and Prepalatial commensal politics), while contextual analysis of some well-defined deposits rich in faunal remains may shed light on individual consumption events. Consideration of the taxa and age/sex groups represented and of butchery evidence may indicate whether different events were marked by the consumption of particular types of meat or by cooking in distinctive ways. A related issue is the possibility that large urban centres, such as palatial Knossos, supported specialised processing of animal carcasses (potentially detectable in standardised or 'careless' butchery marks) and specialised working of bone and horn/antler raw materials. Evidence for the depositional history of the assemblage will also be examined diachronically, to explore the possibility that the changing architectural organisation of Knossos was reflected in changing patterns of refuse disposal.

Animals in religion, ritual and iconography: Interpretation of Bronze Age Cretan iconography frequently rests on the unfounded assumption that the 'realism' of many scenes is a reliable guide to which of the animals apparently depicted (e.g., lions, feral goats, wild bulls) were in fact to be found on Crete. The changing taxonomic composition of the diachronic faunal record from Knossos, combined with palaeontological evidence and biogeographical models, can thus provide important insights into the meaning of some distinctive and recurrent iconographic themes in Minoan art, by clarifying whether the animals and scenes depicted are likely to be real or imagined, commonplace or rare. This is particularly important in assessing the meaning of hunting scenes, which appear to be imbued with exceptional cultural significance.

1.4 Structure of the thesis

In the chapters that follow, Chapter 2 presents a summary of Cretan environment and climate, with particular reference to the Knossos area, and discusses available evidence for environmental change during the Holocene as a basis for assessing the potential of the Knossos area for farming. Palaeontological evidence is also reviewed, in the light of models drawn from island biogeography and ecology, in order to evaluate the argument for anthropogenic extinction

of the Pleistocene endemic fauna of Crete (Lax and Strasser 1992) and to assess the likely composition of the mammalian fauna of the island during the Neolithic and Bronze Age. This allows for an informed discussion in later chapters of the availability of 'wild' animal resources, of the availability of ecological niches for introduced populations of deer or feral domesticates, and of the meaning of iconographic representations of animals.

Chapter 3 presents the archaeological background, starting with a brief summary of the history of the site of Knossos, as this is known from the century-long explorations on the Kephala hill and surrounding area, and ending with a more detailed presentation of the archaeological contexts from which the faunal material studied for the purposes of the present thesis is derived.

Chapter 4 sets out the zooarchaeological methodology employed in the field for data collection, as well as the analytical methods used to shed light on the depositional and post-depositional history of the assemblages from their original discard by humans in prehistory to museum storage today. It concludes by detailing the methods used to investigate human behaviour through zooarchaeological data.

Chapter 5 explores the effects of post-depositional and depositional processes on the assemblages based on the methodology detailed in Chapter 4. Chapter 6 investigates issues of animal consumption and Chapter 7 of animal management. Chapter 8 summarises the insights into Cretan prehistory provided by the present study, concluding with new directions which research might take in order to put bioarchaeological evidence to better use in the future as an integrated and mainstream component of Cretan archaeology.

2 THE NATURAL ENVIRONMENT

2.1 Introduction

The study and understanding of the past natural environment, including climate, geology, geomorphology, fauna and flora of Crete and more specifically of Knossos are crucial. They provide a backdrop against which human societies became established and flourished on the island. They inform us of the possibilities and limitations with which they were presented, and provide us with an informed perspective on their choices and socio-economic strategies. Unfortunately, the geographical location of Crete, its climate and geology favour the preservation of only certain types of proxy environmental records. Localities with the potential to preserve palynological and entomological records are extremely rare. Palynological studies are available mostly from sites located in the western part of the island (Bottema and Sarpaki 2003: 734, fig. 1) and, because of poor preservation, are often patchy in terms of chronological coverage and/or poorly dated (e.g., Bottema and Sarpaki 2003: table 1; Moody *et al.* 1996: 280). Moreover, the geographic configuration of Crete and the strong precipitation gradient, decreasing dramatically from west to east, warn against uncritically extrapolating conditions in the centre and the east of the island from environmental records from the west. Inevitably, any discussion pertaining to climate can only marginally be based on direct evidence, such as pollen records, and by necessity has to draw heavily on present climate, without knowing how much this diverges from that of the mid-Holocene. Finds of Pleistocene mammalian fossils are both more frequent and geographically dispersed across the island, but provide a chronologically coarse record and are less sensitive markers of climate change than plants or insects, while covering only the earlier Pleistocene.

For the immediate area of Knossos, studies of the palaeoenvironmental record are absent, while geology and geomorphology have only been summarily studied (Roberts 1979). The modern vegetation, however, is more amenable to observation, and the fossil record, although not very suitable for reconstructing climate, provides other important information about the availability of resources to prehistoric Cretans. These scant resources are summarised here with the aim of providing a background to animal use and management in Cretan prehistory.

2.2 The natural landscape of Knossos

2.2.1 Location, hydrology, geology, geomorphology, and climate[1]

The central part of the site of Knossos, that is the early Neolithic settlement and main palatial complex dating to the Middle and Late Bronze Age, is located on the Kephala hill, at 90masl and about 5km inland from the Gulf of Herakleio, in the small tectonic valley of the river Kairatos (Figure 2:1a and b). The Kairatos rises from springs in the Archanes area and, despite intensive use for the irrigation of vegetable gardens, still flows year-round. Within living memory, the stream powered a number of water-mills, some of which operated year-round, was deep enough in summer for local children to bathe in and supported fish-life, including migratory eels[2].

The Knossos area consists of two main geological formations. A Cretaceous limestone substrate is overlain to the west of the river by soft Pliocene marls running on a north-south axis. The Kephala hill and the area to the west of the river consist of marls, while the Ailias ridge is formed of limestone, visible on the upper parts of the ridge due to erosion. An outcrop of crystalline gypsum of Pliocene date is visible to the south of the Palace, at *Gypsadhes*. *Rendzina* soils – also categorised as brown forest soils and regosols (Morris 2002: 10) – have developed from the weathering of the Pliocene marls and *terra rossa* soils – red Mediterranean soils and lithosols (Morris 2002: 8) – from the weathering of the Cretaceous limestone (Roberts 1979: 233; 1981: 5) (Figure 2:1c). Finally, the river now cuts through erosional sediments from the surrounding slopes, accumulated in the late Roman period (Roberts 1981: 5).

The mean annual precipitation (476.5mm) and average monthly temperatures (between 15 and 30°C) given by Roberts for the Herakleio area match the typically Mediterranean pattern of mild winters and hot summers with rainfall concentrated in winter months and often absent from late spring to early autumn (Roberts 1979: 233-4); these observations are largely valid for the Knossos valley. Snowfalls and hail storms, though rare, occur occasionally at Knossos (the most recent snowfalls were observed in winter 2004 and a hail storm in early spring 2002). Prevailing winds are mostly northerly and only rarely does a hot southerly wind occur. Elderly local residents, with personal experience of non-mechanised cultivation of cereals, pulses, olives and vines, regard the Knossos valley as a favoured micro-environment within the wider area of north-central Crete: it enjoys deeper and more water-retentive soils than the hills of Archanes

[1] There are no detailed studies of the natural environment of the Knossos area, other than that by Neil Roberts, undertaken in the context of Hood's archaeological survey of the Knossos area (Roberts 1979: 231, note 1; 1981) on which the present summary draws.

[2] Information provided by elderly residents at the modern village of Knossos.

and the Pediada region, to the south, and is largely sheltered from the cold northerly winds that pose a hazard to crop growth on the coastal plain around Herakleio, to the north.

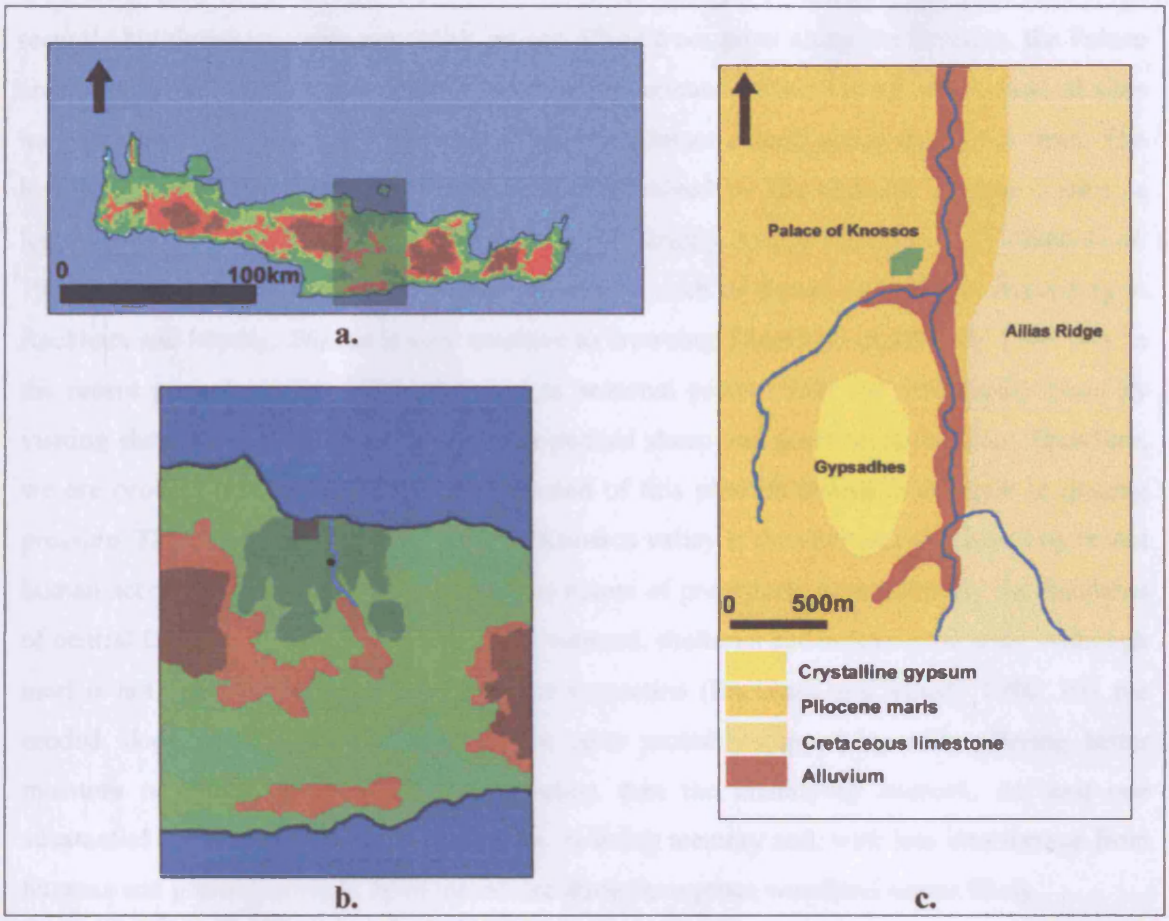


Figure 2:1 Topographic and geological maps
(a) Topographic map of Crete with approximate area shown in (b); (b) Topographic map of wider Knossos area. Dark green: arable land in Herakleio/Knossos/Archanes area; light green: coastal plains; medium green: land <500m; light brown: 500-1000m; dark brown: >1000m; dot marks approximate location of Kephala hill and square marks approximate location of modern Herakleio); (c) geological formations in Knossos area (after Roberts 1979: 236, fig. 3).

2.2.2 Past and present vegetation: natural and human influences

No proxy records of prehistoric vegetation are available from the immediate Knossos area. By necessity, information has to be drawn from the current vegetation cover and pollen records from other parts of the island, in an effort to provide a plausible picture for the past. Evidence is discussed here from two pollen cores, both from the lowlands near Rethymno, which provides the closest possible parallel in terms of altitude and geology to the Knossos area of the available, to-date, palynological evidence.

Based on the altitudinal vegetational zones suggested by Zohary and Orshan the climax communities around Knossos should consist of evergreen maquis comprising wild olive,

pistachio, carob, juniper, and evergreen oak (Roberts 1979: 234). Today the area around the Kephala hill is a mosaic of cultivated land and wild vegetation. The alluvium and lower slopes are mostly planted with vegetables and fruit trees, while parts of the Ailias ridge have been recently bulldozed to create new olive groves. Plane trees grow along the Kairatos, the Palace area is bordered with planted conifers, while other unmanaged but fenced archaeological sites have been invaded mostly by introduced[3] and, to a lesser extent, native deciduous trees. The higher slopes, mostly uncultivated, have been colonised by the endemic *Ebenus cretica*, a leguminous undershrub belonging to a genus with strictly Asiatic distribution (Turland *et al.* 1993: 3), which is mixed with other *garigue* plants, such as thyme, and shrubs. According to Rackham and Moody, *Ebenus* is very sensitive to browsing (Rackham and Moody 1996: 54). In the recent past, the Ailias ridge was used as seasonal pasture and was periodically burnt by visiting shepherds but nowadays only a few penned sheep and goats are to be seen. Therefore, we are probably witnessing a recent expansion of this plant following a decrease in grazing pressure. The present-day vegetation of the Knossos valley is thus extensively shaped by recent human activity and offers few clues as to the nature of prehistoric vegetation. By the standards of central Crete, however, the valley is well-watered, sheltered and enjoys good soils. Although marl is not regarded as a good substrate for vegetation (Rackham and Moody 1996: 30), the eroded slopes of the Knossos valley were once probably capped by soils offering better moisture retention and easier root penetration than the underlying bedrock. At least one substantial deciduous oak grew in the valley in living memory and, with less interference from humans and grazing animals, open mixed deciduous/evergreen woodland seems likely.

Such a possibility may be supported by the findings from the analysis of the pollen cores from the Rethymno area (Delphinos river and Kournas Lake), covering, in combination, a substantial part of the chronological period of interest to the present study (Figure 2:2). Rethymno lowlands experience similar modern precipitation to Knossos (600mm annually) and have comparable soil cover. Based on the pollen evidence, Bottema and Sarpaki (2003) argue for the existence of an open deciduous-oak forest and dry conditions around 7400 and 6300 cal. BC; thereafter arboreal pollen increases from which denser forest cover and wetter conditions are inferred. It is likely that more extensive tree cover was also the case for the Knossos area. Anthropogenic impact is deduced from the appearance of olive pollen in the fourth millennium BC and of carob and walnut pollen from the second millennium BC (Bottema and Sarpaki 2003: 747). A change in sedimentation (from organic material to clay-marl), interpreted as a sign of erosion and linked to the increase of Ericaceae pollen in the upland core of Asi Gonia, in the White Mountains (Atherden and Hall 1999), is taken to indicate increased grazing pressure (Bottema and Sarpaki 2003: 743-5).

[3] A walnut tree was observed near Karavanserai during a visit in July 2004.

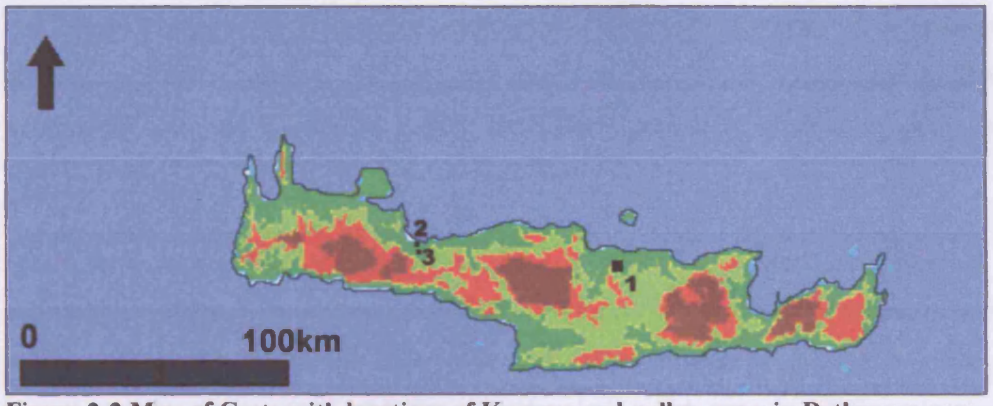


Figure 2:2 Map of Crete with locations of Knossos and pollen cores in Rethymno area (Knossos: 1; Delphinos: 2; Lake Kournas: 3).

2.3 Ancient Animals and Modern Myths[4]

2.3.1 Introduction

The modern fauna of the Knossos area has not been systematically studied. Based on personal observation, however, hedgehogs and rodents are regularly sighted, and badgers and martens more rarely, indicating a range of taxa typical of the modern 'wild' mammalian fauna of the island. The presence of these animals, however, is entirely the result of human intervention (e.g., Jarman 1996).

The discovery of a number of fossiliferous localities (for a gazetteer see Lax 1996) has revealed the existence during the Pleistocene of a *native endemic* fauna of medium- and small-sized mammals (Bate 1905; de Vos 1996: 111). This Mediterranean-wide phenomenon of Pleistocene endemic insular mammalian faunas has been better understood in the last thirty years, thanks to advances in theoretical island biogeography and ecology and the comparative study of extant island faunas. These have stressed the distinctiveness of insular mammalian species and faunal communities and have observed certain recurrent patterns in their development (e.g., MacArthur and Wilson 1967; Whittaker 1998).

Combined in recent years with more systematic palaeontological research – including stratigraphically controlled excavations of fossiliferous sites, where detailed sampling strategies for the recovery of small taxa are also practised – these advances have afforded insights into the creation and development of Quaternary faunas on Crete in terms of colonisation mechanisms

[4] This section was written before the publication of Mavrides' article (Mavridis 2003) which arrives independently at similar conclusions in regards to some issues, for example the chronology of extinctions (Mavridis 2003: 68). Mavridis, however, overlooks recent critiques of theories of human-induced extinctions in the western Mediterranean (Mavridis 2003: 68), and the most probably intrusive character of badger remains in cave sites on Crete (Mavridis 2003: 67), which are discussed in section 2.3.4. Similarly, Vigne (1999) also arrives independently to similar conclusions in relation to the status of taxa archaeologically attested on Crete.

and faunal composition (cf. various articles in Reese 1996). Thus, while palaeontology has provided direct evidence for the composition of faunal communities through time, biogeographical and ecological theory has offered valuable explanatory tools (e.g., Schüle 1993).

Apart from issues such as the mechanisms of colonisation and establishment of founder populations and the development of endemic forms, which have been addressed mainly by palaeontologists (e.g., Sondaar 1986; Mol *et al.* 1996; Sondaar *et al.* 1996; Sondaar *et al.* 1998), the other major focus of research has been the timing and causes of their extinction. The latter have been investigated primarily by archaeologists in connection with the exploitation and colonisation of the islands by human populations during the Quaternary (see reviews by Cherry 1981; 1990; Masseti 2003b; Mavridis 2003; Vigne 1988; 1996).

Realisation of the relevance and importance of such approaches is evident in studies concerned specifically with Cretan prehistory (e.g., Broodbank and Strasser 1991; Lax and Strasser 1992). Here discussion begins with a review of these studies in the light of more recent evidence, and then considers the potential of these approaches to shed light on other issues such as the status (indigenous or introduced) of species attested in faunal assemblages, art or texts, and the symbolic and dietary importance of hunting.

2.3.2 Which endemic animals on Crete and why?

The sea acts as a filter to dispersal of animals from larger landmasses to islands, resulting in the creation of *impoverished, unbalanced endemic* faunas on islands (e.g., Sondaar *et al.* 1996: 62). Insular faunas are characterised as impoverished and unbalanced because carnivores are normally absent; most are bad swimmers and their feeding and metabolic requirements necessitate the existence of large populations of herbivores to maintain viable predator populations. Some herbivores, however, are better adapted to surviving sea-crossings, most typically elephants, hippopotami, deer, murids and rodents. Endemic forms of these develop due to a combination of factors like isolation, reduced gene pools[5], absence of predators and possible periodic food scarcity. These factors favour phenomena like *dwarfism* in larger taxa and *gigantism* in smaller bodied mammals and result in the development of particular insular types: pygmy elephants, hippopotami and deer and giant rodents (summary in Schüle 1993: 403-4).

[5] The model supposes that successful crossings will be few and far between.

As has been pointed out by several researchers, the taxonomic composition of Pleistocene palaeontological assemblages on Crete is compatible with what is expected for an 'oceanic' island, isolated from the nearest large landmass for a geologically long period of time. Based on geological evidence Crete *has* been separated by sea from the nearest landmass, the Peloponnese, for about 6 m.y. (Fassoulas 2000: 33, fig. 11). The geological and palaeontological data fit Sondaar's 'sweepstake dispersal' model (Sondaar 1986): the island was colonised during the Pleistocene by taxa which dispersed more successfully than others due to their capacity to survive the crossing of large stretches of sea by swimming (deer, hippopotami and elephants) or drifting (rodents) (summary in Schüle 1993: 402-3).

2.3.3 A faunal turnover during the Pleistocene?

Although a considerable number of localities with Pleistocene fossil remains were known on Crete, the absence, for a long time, of stratigraphically controlled excavations made the chronological relationship between the various taxa identified unclear. Recently, more systematic excavation methods have allowed a better understanding of the composition and chronology of these faunas. A review of the existing data (for summaries of previous work and results of recent analyses, see Reese *et al.* 1996; Sondaar *et al.* 1996; de Vos 1996) suggests the existence of two distinct biozones during the Pleistocene (see Table 2:1).

The earlier *Kritimys* biozone comprised endemic forms of pygmy hippopotami, pygmy elephants, large murids and a soricid but *no* deer. This fauna became extinct probably in the Middle Pleistocene (de Vos 1996: 115; Sondaar *et al.* 1996: 65).

The later *Mus* biozone comprised up to eight species of endemic deer and two elephant species (*Elephas antiquus* and *Elephas creutzburgi*) (de Vos 1996: 113-5). The elephants do not show strong signs of endemism (Mol *et al.* 1996: 93). Two endemic species of small murids were also present (Mayhew 1996: 169) and the soricid which apparently survived from the previous period. A carnivore (*Lutrogale cretensis*) has also been identified but is compatible with an island fauna since it belongs to an originally aquatic species and is known to be part of other insular faunas (Willemsen 1996: 155).

Table 2:1 Endemic Pleistocene mammals of Crete
(data for murids from Mayhew 1996: 169; ESR and AAR dates from Reese *et al.* 1996).

Biozones	Dates (bp)	Medium sized mammals	Carnivores	Murids	Soricids
Kritimys	846,000-378,000±20%	*Hippopotamus creutzburgi*		*Kritimys kiridus*	*Crocidura zimmermanni*
		Elephas creticus		*Kritimys catreus*	
Mus	152,000-21,500±20%	*Elephas antiquus*	*Lutrogale cretensis*	*Mus batae*	*Crocidura zimmermanni*
		Elephas creutzburgi		*Mus minotaurus*	
		Endemic deer			

Thus, with the exception of *Crocidura zimmermanni*, a complete faunal turnover appears to have taken place between the two biozones. Pigmy hippopotami are absent from the later, *Mus* biozone, while a number of endemic species of deer are encountered in the Pleistocene fossil record for the first time. This contrasts with the evidence from Cyprus, where it is argued that the endemic pygmy hippopotamus (*Phanourios minutus*) survived into the 10th millennium cal. BC and was hunted by hunter-gatherer groups (Simmons 1999; 2001).

The substitution of hippopotami by deer may be related to biogeographical factors, that is, which species were present at the time on the nearest mainland, the Peloponnese, which Sondaar considers the most likely source of the ancestors of Cretan endemics on the basis of morphological similarities. Unfortunately, our understanding of the biogeography of the Peloponnese is rather poor due to the limited number of Pleistocene fossil locations (Sondaar *et al.* 1996: 64), but the scenario seems likely given the prevailing north-south winds and currents between the two landmasses. In the same analysis, morphological comparisons suggest no connection between the Cretan endemic deer and those of the islands of Kasos and Karpathos to the east (Sondaar *et al.* 1996: 64). This may be a result of prevailing winds and currents between Kasos and Crete (Agouridis 1997), which would have swept any crossing animals into the open sea. The causes of the turnover are currently unclear, but Spaan speculates that it could be attributed to sea level and climatic changes combined with an influx of new mainland species, which outcompeted the specialised endemics (Spaan 1996: 108). The make-up of the endemic fauna in the more recent – *Mus* – biozone, however, in combination with the available dates, is of most interest, especially in view of the argument for the human involvement in the extinction of the endemic Cretan fauna proposed by Lax and Strasser (1992).

2.3.4 The Lax and Strasser model

In their 1992 article, Lax and Strasser examined the then available evidence for likely causes for the extinction of the Cretan endemic mammalian fauna. They rejected the possibility of

extinction due to climatic reasons or overkill and proposed a model originally put forward by Diamond (1984; 1989) to explain other cases of extinctions and termed by him '*Sitzkrieg*' in reference to Mossiman and Martin's (1975) '*Blitzkrieg*' model, that is the extinction of mammals by humans through overkill. Following Diamond's model, Lax and Strasser suggested that the last of the Cretan endemic fauna may have become extinct as a result of indirect human impact, namely through habitat loss because of agricultural practices, and through competition for resources between indigenous animals and the fauna introduced by the Neolithic settlers, sometime in the beginning of the 7th millennium B.C.

The evidence and arguments used by Lax and Strasser to support indirect human impact were:

- A late ^{14}C date on hippopotamus remains from the Katharo basin on Crete (12,135±485 BP) (Lax and Strasser 1992: 208);
- Co-existence with humans and later extinction of several endemic species on other Mediterranean islands (Lax and Strasser 1992: 208-9);
- Survival of some of the Cretan endemic species into the Neolithic, as attested by remains at localities where skeletal remains of endemic animals were reported to have been found in association with human artefacts dating to the Neolithic (Lax and Strasser 1992: 210);
- The presence of particular species thought to be endemic (deer, badger, marten and *Mus*) in Aceramic and Early Neolithic levels at Knossos (Lax and Strasser 1992: 211, quoting Cherry 1990: 163).

Based on the above, Lax and Strasser argued that, since some of the indigenous species survived until the arrival of Neolithic settlers, their eventual demise was unlikely to be a result of a climatic change. Such a change should equally have affected all taxa. The overkill model was rejected on the basis of rather complex argumentation (Lax and Strasser 1992: 215), but essentially because there is no evidence to-date for pre-Neolithic hunter-gatherer presence on the island (see section 2.3.6). Thus, the authors concluded that Diamond's *Sitzkrieg* model is the most appropriate for the extinctions on Crete. Although their argument is theoretically correct, it is no longer supported by the available data: this new evidence is discussed in detail below.

First, the Katharo date on pygmy hippopotamus remains has been rejected as the researcher has admitted that it is 'possible that the [^{14}C] sample had some deficiency' (Zapfe quoted in Reese *et al.* 1996: 47). AAR and ESR dating of samples from the same locality has pushed the dates of these remains a lot further back (Table 2:1), considerably earlier than the first documented settlement of people on the island in the seventh millennium (Knossos Stratum X, J.D. Evans

1994: 1), a point also made by Mavridis (Mavridis 2003: 68). Secondly, already in his 1990 article Cherry refers to the debate over the relationship between evidence for human activity and remains of island endemics in various locations and therefore the validity of some of the statements concerning the survival of endemic mammals in other Mediterranean islands. From his discussion it is obvious that, at the time, there was still not enough positive evidence for overlap between Neolithic populations and endemic mammals on any of the Mediterranean islands, while such overlap with pre-Neolithic hunter-gatherer groups is still debated, except perhaps for Cyprus (Simmons 1999). Below the evidence considered by Lax and Strasser to provide support for the applicability of the '*Sitzkrieg*' model in Mediterranean islands is discussed, together with the current state of research in this area.

Cherry in his 1990 review is sceptical of the evidence from Mallorca, where the endemic antelope *Myotragus balearicus* was until recently thought to have survived the Neolithic colonisation by humans only to become extinct in the Bronze Age (see review in Cherry 1990: 184-9). On the basis of existing evidence, *Myotragus* is not likely to have survived into the Neolithic and to have been exploited by humans – see also Schüle's interesting view on why this is an unlikely scenario (Schüle 1993: 407). A few recent studies have convincingly refuted most arguments for human – *Myotragus* co-existence. Pérez Ripoll's study of the bone remains from the rock-shelter of S'on Matge – considered by Cherry to be the best evidence for human-*Myotragus* co-existence (Cherry 1990: 186-7) – has shown that what was taken to be human modification of *Myotragus* bones was probably inflicted by the animals themselves (Guerrero Ayuso 2001; Pérez Ripoll 2002). The supposed tools bore very close resemblance to gnawing patterns inflicted by deer on bones and antlers of individuals of the same species, a habit observed in nature and under experimental conditions (e.g., Kierdorf 1993; Sutcliffe 1973, 1977) and has led to erroneous interpretation in many instances in the past (e.g., see Cherry's discussion of the refutation of Kuss' *Osteokeratic culture* [Cherry 1990]). Similarly, Vigne *et al.* come to the conclusion that, in the case of Corsica, *Mega(lo)ceros*[6] *cazioti* and *Cynotherium sardous* 'may have become extinct before the colonisation in the Holocene of the island by modern man' (Vigne *et al.* 1997: 599). In Corbeddu cave, in Sardinia, bones of the endemic *Mega(lo)ceros cazioti* appear for the last time in a layer dated to 9120±380 (uncal. bp), which makes it contemporary with occupation levels considered pre-neolithic at other Corsican sites (Cherry 1990: 176). The anthropogenic character of the modifications on those (few) bones is also contested however, while the Neolithic levels (Layer 1) contain no *Mega(lo)ceros* remains (Pérez Ripoll 2002). As regards smaller mammals, things are more complicated. Murids apparently survived the arrival of humans in Corsica and Sardinia, but for Crete, our understanding of the Holocene history of equivalent species (see below) or of their feeding

[6] This convention is adopted here, as spelling varies between different sources.

habits and environmental requirements is very poor, while there is no equivalent to *Prolagus* in the Cretan endemic fauna. Thus, murid remains cannot be used at present as evidence to support either side of the argument.

Thirdly, the number of sites on Crete where remains of endemic animals have been found in association with evidence for human presence is small and the contemporaneity of endemic faunal remains and human activity questioned (see reviews by Hamilakis 1996a; Jarman 1996; Lax 1996). Such claims have been convincingly refuted in two instances, Gerani cave III, briefly studied by Jarman (1996: 215-6) and Sentoni cave studied by Hamilakis (1996a: 234-5). At both sites, fragmentation patterns, skeletal element representation and degree of mineralization have been shown to be consistently different between the remains of indigenous animals and those of domesticates, or other anthropogenically-introduced animals, suggesting different processes of accumulation and different ages for the skeletal materials (Hamilakis 1996a: 236; Jarman 1996: 216).

Fourthly, Lax and Strasser quote Cherry (1990: 163) as saying that 'Aceramic and Early Neolithic Knossos are reported to have yielded bones of deer (*Cervus*), badger (*Meles*), marten (*Martes*) and mouse (*Mus*)' and also list ^{14}C dates for these periods. In fact, Cherry himself does *not* state that any of the above animals were found in Aceramic and Early Neolithic levels at Knossos; what he actually writes is 'The relatively sparse finds at *Neolithic* [emphasis added] Knossos of wild animal bones (including deer, badger, marten and mouse: Jarman n.d. [now published and referred to here as Jarman 1996]; Jarman and Jarman 1968; Winder in prep. [presumably Winder's thesis]) give rise to the suspicion that "by the time the Neolithic settlers arrived on Crete there was not much left to hunt" (Moody 1987a: 145)'. Lax and Strasser also mention the remains of *Meles* and *Martes* from Simonelli cave and thus infer that *Martes* and *Meles* may be part of the indigenous Cretan fauna and that they and indigenous deer and *Mus* may have survived into the Neolithic. The evidence for such survival is reviewed here for each of these taxa.

The earliest *deer* remains at Knossos were reported by Jarman from *Late* Neolithic levels (Jarman 1996, table 18.1) and were identified as *Cervus elaphus* – morphologically quite distinct from the endemic deer (Halstead pers. comm.[7]). The Late Neolithic deer cannot but be human introductions on present evidence. Moreover, there is a considerable time gap between the most recent dates on skeletal remains of endemic animals (Table 2:1) and the earliest so far documented human presence on the island represented by Stratum X at Knossos. Had the endemic deer survived into the 7th millennium BC, they are unlikely to have been completely

[7] Dr. Halstead examined the Gerani material in the 1980s at the invitation of the excavator, Dr. Tzedakis.

ignored by the Neolithic settlers and some evidence of their use would arguably have survived (Hamilakis 1996a: 236).

Following Cherry (1990) who took his information from Davis (1987), Lax and Strasser state that *Martes martes* (marten) and *Meles meles* (badger) belong to the Cretan indigenous fauna. It is indeed true that they both occur in fossil locations with remains of indigenous fauna. In all cases, however, either there is evidence of human activity dating to the Neolithic (Table 2:2, entries 1 and 2) or the stratigraphic relation between these two species and the endemics identified in each location is unclear or unknown (entries 3 and 4). Kotsakis also characterises the Simonelli cave material as 'subfossil' as far as its preservation state is concerned, and therefore younger than the rest of the remains (Kotsakis 1990). Steensma and Reese (1996) discuss the available evidence and conclude that the animals in the locations below are unrelated to the remains of the indigenous fauna and should be considered as human introductions. They point out that mustelids are unlikely candidates for an impoverished island fauna, as they lack the swimming capacities of deer, elephants and hippopotami and are not successful drifters like murids (Steensma and Reese 1996: 164). What is not mentioned in any of the studies is that the mixing of natural and anthropogenic strata may result from disturbance by badgers, as these are burrowing animals. Thus, it is even questionable whether badger bones in Neolithic levels are indeed contemporary with the deposits and not later intrusions, as for example the remains of *Meles* occurring in the Aceramic Neolithic levels at Knossos may be (Jarman 1996, table 18.1). It should be pointed out, however, that analysis of faunal assemblages from the earliest now known Neolithic (9th millennium BC) on Cyprus shows that small mammals such as fox and cat were introduced to the island by humans with the larger mammals (sheep, goats, deer and cattle) (Vigne *et al.* 1999). Direct dating of bones would be a means of resolving this issue.

Table 2:2 Palaeontological sites with remains of *Martes* and *Meles* (data from Lax 1996).

Location	Faunal material associations	Type of investigation	Reference
Liko Cave	Found in upper strata which also contained sheep/goat/rat	Detailed formal excavations conducted by palaeontologists	Lax 1996: 9; Steensma & Reese 1996:159, 161
Gerani Cave II	Contained Neolithic material and *Sus/Rattus/Oryctolagus*	No data (probably not excavated)	Lax 1996: 11; Steensma & Reese 1996: 159, 161
Mavromouri Cave I	Endemic deer and *Meles* skull; no Holocene animals reported	No formal excavation conducted	Lax 1996: 15; Steensma & Reese 1996: 161
Mavromouri Cave VII	Endemic deer, *Martes foina* skull; no Holocene animals reported	No formal excavation conducted	Lax 1996: 16; Steensma & Reese 1996: 159
Simonelli Cave	Contained Neolithic material	Excavation conducted by palaeontologists	Lax 1996: 18; Steensma & Reese 1996: 164

As regards small mammalian fauna, there is only one detailed study of microfauna from an archaeological site, Kommos (Payne 1995), where only one of the species identified in palaeontological contexts is also attested in Bronze Age deposits. The species is *Crocidura zimmermanni*, and small populations are apparently still extant at high altitudes on Crete

(Reumer 1994). It is unclear whether the *Mus* remains in Early Neolithic levels at Knossos (Jarman 1996: table 18.1) belonged to the endemic species or were introduced by humans. Indeed Jarman states that he has been 'unable to determine whether the murids from Knossos belong to this species or whether they should be referred to *Mus musculus*, the Recent House mouse, which is present on the island today' (Jarman 1996: 214). Specialists involved with the study of the endemic Cretan murids (e.g., Mayhew 1996) do not give information about how these compare with *Mus* remains from archaeological contexts, and whether indeed there is a way of distinguishing between the two other than on the basis of size. It should be noted that no metrical data were ever published for the Early Neolithic *Mus* remains from Knossos. Work currently under way, to establish morphological differences between dentitions of endemic and introduced murids, may clarify this issue (Cucchi *et al.* 2002).

2.3.5 Why the '*Sitzkrieg*' model may not be appropriate for Neolithic Crete

In the light of new evidence and re-analysis of older material, the arguments put forward by Lax and Strasser are problematic. For Crete in particular, there is still a large chronological gap between the available (admittedly few) dates for the last documented indigenous animals and the first certain establishment of humans on the island. Apart from one small mammal, *Crocidura zimmermanni*, which survives to the present (Reumer 1996: 177) and has also been identified in the zooarchaeological record (Payne 1995), there is no evidence that any of the demonstrably endemic species existed at the time of the first certainly attested establishment of Neolithic farmers. Indeed, endemics are so far manifestly absent from the zooarchaeological record and it seems unlikely that the Neolithic inhabitants of Crete would have completely ignored any putatively surviving indigenous deer. Comparative evidence from other areas suggests that it is unlikely that a *naïve* fauna – such as one would expect on Crete in the absence of predators – would nothave been hunted by humans intensively enough to leave archaeological evidence (Schüle 1993: 406-7; cf. moa kill sites cited in Simmons 1999: 326; *contra* Lax and Strasser 1992: 215).

There are other reasons why Diamond's *Sitzkrieg* model may not be appropriate. In his examples, on the one hand, the whole process of extinction was completed over long spans of time, often millennia, in which case evidence for co-existence of humans and extinct animals should survive (Diamond 1989: 171). On the other hand, the final demise of several of the species he mentions, was effected by human population densities and the implementation of modern intensive farming and animal breeding methods and technology (Diamond 1989: 169-70) by no means paralleled by early Neolithic communities: the small-scale intensive farming and animal breeding suggested by the available evidence (Halstead 2000) would not have

produced the level of disruption of the ecosystem required for extinctions. One practice may have had a more serious impact, burning to improve pasture and browse for animals, especially if this occasionally got out of control. Evidence for this could be provided by examining charcoal concentrations in the pollen record (Halstead 2000: 114), but there is so far limited evidence of this type from Crete (Atherden 2000). Admittedly, deposits suitable for pollen preservation are rare in the Cretan environment, but at present there is no evidence for such practices in this period.

2.3.6 Pre-Neolithic hunters on Crete?

On present evidence, it is most economical to conclude that Neolithic settlers had no involvement in the extinctions of Cretan endemics. What about earlier hunter-gatherer groups, for whom there is evidence for open sea voyaging in the Aegean? Seafaring is attested by the presence of obsidian in the Upper Mesolithic levels at Franchthi cave in the Peloponnese (Perlès 1987: 142-5) procured on the Cycladic island of Melos (Renfrew and Aspinall 1990). No evidence on Crete of either permanent establishment or visitation by such groups exists to date (Broodbank 2000: 113; Cherry 1990; Runnels 1995: 728; Broodbank and Strasser 1991: 235). Nevertheless, it is unlikely that humans had never set foot on Crete either deliberately or accidentally before the Neolithic, given the large size, configuration and topography of the island. These features make it highly visible from several miles out to sea while prevailing winds and currents from the north make it the most likely accidental landfall of anyone blown out into the open sea in the course of voyaging around the Cyclades (Broodbank and Strasser 1991: 235). Absence of evidence need not, of course, be evidence of real absence. Loss of Upper Palaeolithic and Mesolithic sites due to eustatic sea-level rise since the end of the Last Glacial is likely – although the impact cannot have been as extreme as in some other areas of the Aegean, given the configuration of the Cretan coastline (Figure 2:3).

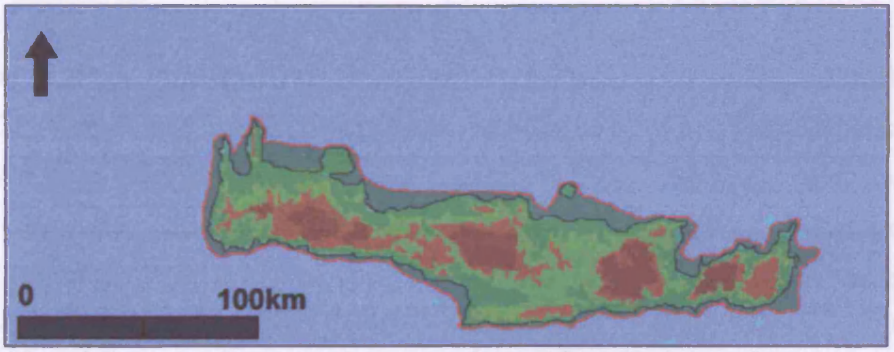


Figure 2:3 Map of Crete showing approximate coastlines at Last Glacial maximum. Approximate coastlines outlined in red (after Broodbank and Strasser 1991: fig. 1, based on van Andel and Shackleton 1982: figs. 2 & 3).

Factors like erosion and alluviation must have transformed the Cretan landscape, at least in part, since the Pleistocene (Cherry 1990: 201; Pope 1993). Nothing can be said with certainty, however, as our understanding of the development of Cretan geomorphology during the Quaternary is deplorably poor, based on preliminary publication of only one systematic geoarchaeological investigation (Pope 1993). Moreover, very few *intensive* archaeological surveys have been undertaken on Crete to date. Extensive surveys have been by far the commonest method of locating sites (Watrous 1994: 697-8) with all the concomitant problems, while the wealth of sites from later periods – the Bronze Age in particular – has attracted scholars of relevant skills and interests. This has often raised the question of whether absence of pre-Neolithic sites may be due to low visibility of artefacts made and utilised by purported hunter-gatherers, which make them very difficult for non-experts to identify in the field.

Although it is always possible that an Akrotiri-*Aetokremnos*-type site may one day be discovered on Crete, the numerous sites, investigated to date, which contain remains of indigenous fauna, have failed to produce convincing evidence for a relationship between its remains and human activity either before or during the Neolithic (Cherry 1990: 158; Hamilakis 1996a; Strasser 1992). If such locations continue not to be found, it is tempting to attribute the absence of evidence for hunter-gatherer occupation/visitation to the lack of any substantial game resources in the late Pleistocene and earliest Holocene. This would have rendered the risky sea crossing unappealing as a deliberate venture, while, in the event of an unintended landfall, it may have been necessary to undertake the return voyage as soon as possible. Such brief visits would have left evanescent evidence of human presence and could account for the failure to locate any sites from this period. This possibility is pre-empted by Cherry who concludes that 'the scarcity of Palaeolithic sites in the Mediterranean islands begins to look more like the result of avoidance, than of ignorance or inability on the part of potential colonists' (Cherry 1990: 202). Such a scenario would best fit his visitation model for Crete (see also Broodbank and Strasser 1991: 236-7).

As for the tendency to assume parallel trajectories for the two large Eastern Mediterranean islands, Cyprus and Crete, this appears to be increasingly unwarranted by the evidence. It is not necessary that developments on Cyprus are relevant to Crete. Akrotiri-*Aetokremnos* provides evidence 'for a short-term occupation during the tenth millennium B.C. centred around 9825 cal. B.C.' (Simmons 1999: 208). The excavator, after long public debates about the relationship between the animal remains and human activity (e.g., various articles in *Journal of Mediterranean Archaeology* 1996, Vol. 9:1), has produced some convincing arguments combining various specialists' report to support his original interpretation of the location as a

pygmy hippopotamus kill-site, briefly occupied by hunter-gatherers (Simmons 1999; 2001; but see also the critique by Vigne *et al.* 1999: 50-1).

Significantly, pygmy hippopotami appear to have survived a lot later on Cyprus than on Crete. Whether this is a result of climatic or biogeographical causes (e.g., available pool of hippopotamus populations on the mainland close to Cyprus) is outside the scope of this study. It is important to note, however, that even on Cyprus, where we now know that there were animals to be hunted into the early Holocene, no claims can be made for hunter-gatherer groups permanently present on the island. No other such sites are known on Cyprus (Simmons 1999: 332), while one should bear in mind that Cyprus is located opposite an area, which, in the period of use of the Akrotiri-*Aetokremnos* site, is fairly densely populated (at least compared to mainland Greece and Asia Minor) by the complex sedentary hunter-gatherer groups of the Natufian culture.

2.3.7 Conclusion

The above review argues that neither palaeontological and archaeological data nor island biogeography and animal ecology support a Neolithic human-induced extinction of the endemic Cretan mammalian fauna. However unfashionable it may sound, on present evidence, a climatic explanation for the Cretan extinctions is most probable, although it is not implausible that it was aided by human predators in the Late Glacial – Early Holocene transition at an inopportune time for the animals. Although climatic explanations have been rejected for Late Pleistocene extinctions on large landmasses such as Europe and America (see various papers in Martin & Klein 1984), islands represent more fragile ecosystems. If Sondaar's two biozones are correct, there seems to have been one faunal turnover some time during the Upper Pleistocene. If one turnover took place, why not another? More systematic excavations and dating of palaeontological locations on Crete may help clarify this issue. To support a climatic explanation a review of the available climatic data for the period would be necessary, but this is outside the scope of the present study. In any case, Lax and Strasser's proposed explanation based on Diamond's *Sitzkrieg* model lacks any factual or theoretical support in the case of Neolithic Crete.

Thus, we can conclude that when the first Neolithic colonists arrived on the island some time in the early 7th millennium BC, there was nothing bigger to hunt than a shrew. The Neolithic farmers had to rely for meat and hides on their own domesticates and on any 'wild' animals which they introduced on the island. The absence of indigenous large wild mammals has two further implications of relevance here. First, the development of feral populations of escaped domesticates (as evidently happened at some stage on Crete with feral goats, or agrimia) will

not have been impeded by wild competitors. Secondly, the distribution of evergreen maquis and garigue in Crete today is conditioned by a range of ecological stresses, including grazing, burning and draught. While palynological evidence may indicate lower rainfall than today at the start of the Cretan Neolithic (Bottema and Sarpaki 2003), the absence of large grazing/browsing animals will have removed one factor favouring stress-tolerant evergreens at the expense of more competitive deciduous trees.

2.4 Summary

Evidently, our understanding of the environment of Knossos during prehistory is very poor, but the scant available data suggest the following tentative conclusions: that the climate was not dramatically different from that of today; that the slopes of the Kairatos valley carried a deeper soil cover than today; that the local vegetation included a mixture of evergreen and deciduous trees, the latter growing especially on the better arable soils; and that the endemic fauna had disappeared before the arrival of Neolithic colonists.

The location of Knossos in a sheltered valley with a soft geological substrate, a perennial stream and mild climate would have made it a prime location for farming of cereals and pulses. Extrapolating from the experiences of elderly living residents of Knossos, crop failures of varying severity, due to drought, hot southerly (*livas*) winds and cold northerly (*xirovori*) winds, would have taken place a few times per human generation, although the perennial flow of the Kairatos may have allowed irrigation as at least a partial response to drought. The available local vegetation, initially at least probably comprising a mixture of deciduous and evergreen arboreal taxa, would have been suitable for browsing goats, cattle and pigs although not ideal for grazing sheep. Pasture more suited to sheep would have been found on any land under cultivation, perhaps on the top of the Ailias ridge and, at a greater distance, on the summits of the higher mountains.

Finally, in the likely absence of native mammalian fauna, humans would have been entirely dependent on introduced animals, domesticate or wild, as sources of animal protein and as objects of hunting – an activity prominent in Bronze Age iconography. The absence of native large mammals will also have left a niche, non-existent on mainland Greece, in which escaped domestic animals may have been able to establish feral populations.

3 KNOSSOS: THE HISTORY OF THE SITE AND THE ARCHAEOLOGICAL CONTEXTS OF THE FAUNAL ASSEMBLAGE

3.1 Introduction

This chapter puts the faunal evidence from Knossos in its archaeological context, by presenting a brief history of the site, during the periods of relevance to the present study (7th to 2nd millennium BC (Table 3:1), followed by a more detailed presentation of the deposits from which the faunal assemblage derives. As will become evident, our understanding of the history of Knossos is very uneven, both thematically and chronologically, depending partly on the level of detail to which archaeological material has been analysed and published, but most importantly on the degree to which later activity has disturbed, destroyed, or concealed earlier phases. On the other hand, it is not possible, or indeed relevant, in the context of the present thesis to discuss particularities of the archaeological record. Before proceeding it is necessary to explain Knossian Neolithic chronology, so that the present analysis can be situated in a wider Aegean context.

3.2 Knossian Neolithic chronology

J.D. Evans' analysis of the history of Neolithic occupation was based on stratigraphy, architectural phasing of buildings (when available) and pottery sequences. Using the first two, deposits from his first campaign (henceforth Evans1) in the Central Court were attributed to ten phases, each known by a Roman numeral (I-X), while deposits from the second campaign (henceforth Evans2), but only from the West Court, were labelled with Latin alphabetic characters (A-P) (J.D. Evans 1994: 4, table I). Each of these phases was dated using the pottery sequence devised originally by Mackenzie and 'modified and refined' subsequently by Furness (J.D. Evans 1994: 2, footnote 6), in her typological analysis (of shapes and decoration) of the Neolithic pottery excavated by Arthur Evans earlier in the 20th century. Mackenzie appears to have applied the tripartite scheme used for all prehistoric pottery at Knossos, dividing the material into Early, Middle and Late depending on stylistic and morphological changes. Furness followed his scheme, and was unable to use stratigraphy, as deposits had been dug by Arthur Evans mostly using arbitrary 1m spits, rather than following stratigraphy (Hatzaki pers. comm.).

The use of this terminology means that phases sharing the same 'name', e.g., Early Neolithic, can have very different chronological spans in different areas. This problem is particularly acute as regards Knossos. Its isolation from the rest of the Aegean for most of the Neolithic, combined with the slow development of pottery styles, made the integration of the site into Aegean cultural sequences particularly problematic (Tomkins 2001: 476-80). The problems posed by A. Evans' sequence were rectified somewhat by the advent of ^{14}C dating and, thanks to J.D. Evans' excavations, some calibrated ^{14}C dates have been available for some time now. As Tomkins has pointed out, however, due to the limited number and large standard deviations of the ^{14}C dates available, the problem has not been resolved, and the incompatibility of the breakdown of Knossian ceramic phases and those from other parts of the Aegean is a constant source of confusion. Through a more detailed analysis of the ceramic evidence and more careful assessment of comparanda, Tomkins has attempted to break down the very long ENI phase at Knossos and provide a concordance with other areas of the Southern Aegean for all phases of the Knossian Neolithic (Tomkins 2001: 485-506, 526, fig. I.7). The present study uses his breakdown of ENI and his concordances for absolute chronology, combined with calibrated values of the available ^{14}C dates, calculated by Dr. J. Conolly using OxCal (Table 3:1).

Table 3:1 Knossian Neolithic and Bronze Age chronology
(BA and Greek mainland dates after Broodbank 2000: fig. 1; absolute dates are approximate, due to the paucity of 14C dates for the Neolithic – see section 3.2 below; subdivisions of ENI following Tomkins 2001).

Years cal BC (approx.)	Knossian Pottery Sequence	*Evans1 Strata*	Greek Mainland	Major events
1000				Post-palatial
	LM IIIB / IIIA		LBA	Final Palace
	LMII			
	LMIB / LMIA / MMII			New Palace
	MMII		MBA	Old Palace (early writing and administration)
	MMIB			
2000	MMIA			? Formation of palaces
	EMIII		EBIII	
	EMIIB		EBII	Large scale re-organisation of the area under later CC First Cycladic imports at Knossos
	EMIIA			
	EMI		EBI	? Evidence for feasting (PW) Secondary products Revolution? Settlement expansion
3000				
	LN/FN	Stratum I		Early metallurgy
3500		Stratum II	FN / LN	
4000	MN/LN	Stratum IIIa		
		Stratum IIIb		
4500	ENII	Stratum IV		Cattle figurines Spinning and weaving equipment New pottery shapes
5000	ENIc	Stratum V		
	ENIb	Stratum VI	MN	Pisé construction
5500		Stratum VII		
6000	ENIa	Stratum VIII		
		Stratum IX	EN	Earliest pottery
6500	Aceramic			
7000		Stratum X		Mudbrick construction Introduction of 'Neolithic package' Earliest settlement

3.3 A brief history of Knossos

3.3.1 The Neolithic period

3.1.1.1 *Colonisation*

On present evidence, occupation was established on the Kephala hill in the early 7th millennium cal. BC by a farming community (J.D. Evans 1994: 1). The findings of the first campaign led J.D. Evans to conclude that this initial occupation was temporary (J.D. Evans 1964: 142) – hence the term 'Camp' by which the earliest settlement is often referred to in the bibliography. This interpretation was later revised, following the discovery of more permanent structures of mudbrick, and permanent occupation from this earliest date was deduced (J.D. Evans 1971: 101). The absence of pottery in these levels led the excavator to characterise this phase as 'Aceramic', which he qualified as the absence of the 'use of baked clay for containers' (J.D. Evans 1971: 99). The bioarchaeological evidence suggested that this was a fully farming community: emmer, einkorn, barley (naked and hulled), possibly bread wheat and lentils were identified by Helbaek (J.D. Evans 1968: 269), and the complete range of early farmyard animals – cattle, sheep, goats and pigs –was identified by the Jarmans (Jarman and Jarman 1968: 241)[1]. The now questionable identification of bread wheat[2] among the archaeobotanical remains led J.D. Evans to argue for a western Anatolian origin (J.D. Evans 1968: 274), although he underlined the tenuous nature of his argument (J.D. Evans 1994: 5).

The first settlers have been convincingly described as 'early colonizing farmers' for two main reasons. First, the lack of evidence for long-term occupation of the island by pre-Neolithic human groups makes it unlikely that a viable indigenous population existed, which could have adopted farming (Broodbank and Strasser 1991: 236-7). Secondly, the full 'Neolithic package' of domestic plants and animals, none of which are native to the island, is present from the earliest occupation (Broodbank and Strasser 1991: 236); apparently selective adoption of components of the package on some western Mediterranean islands, interpreted as local adoption of the Neolithic economy (Lewthwaite 1986; 1989) is not attested here (Broodbank and Strasser 1991: 236).

[1] Earlier discussions (e.g., Winder 1991), questioning the Jarmans' identification of sheep and goats as domestic (Jarman and Jarman 1968: 256-61), have become obsolete due to a better understanding of the natural geographical distribution of their wild progenitors (e.g., Uerpmann 1987) and need not, therefore, be discussed here. As for cattle and pigs, although wild animals are attested archaeologically in mainland Greek sites since the Mesolithic and a local domestication of animals imported from the mainland is not impossible, their arrival on Crete with the rest of the 'Neolithic package' would suggest that these are domesticated animals from eastern populations.

[2] The criteria available to Helbaek at the time are considered by specialists today to have been inadequate for a reliable identification (Halstead pers. comm.).

3.1.1.2 *The growth of the settlement*

The initial settlement appears to have expanded during the course of the Neolithic, implying an attendant population increase. The 'growth of the settlement' was the major focus of interest for J.D. Evans, who geared his second campaign towards addressing this question. While details of the use of space, architecture and technology were not presented in detail, it was concluded that the settlement expanded gradually from the Aceramic phase through to the end of ENII based on the distribution of deposits of different ceramic ages (J.D. Evans 1971; 1994). A further estimate of the extent of the MN and LN settlement was attempted, based on the presence of deposits as far as the Royal Road (J.D. Evans 1971: 114). The site was estimated to have expanded *gradually* (J.D. Evans 1971: 115) from 0.25 hectares in the Aceramic (J.D. Evans 1971: 103), representing some 25-50 individuals (J.D. Evans 1994: 4), to 11 hectares in the Late Neolithic representing a population of 1000-2000 (J.D. Evans 1971: 116).

The topic of settlement and population size was taken up subsequently by Broodbank, who pointed out that the inferred size of the community in ENII – above 300-600 inhabitants – is likely to represent an important turning point, as egalitarian relations were 'liable to have been replaced through consensus or conflict by more complex social structures, commonly featuring an increased number of social roles, more asymmetrical power relations, and/or some form of hierarchical organization' (Broodbank 1992: 42-3). Broodbank's analysis was questioned by Whitelaw, who pointed out the patchy information available for the extent of deposits in each period – for example some areas at the edges of the settlement, such as the westernmost trench ZH, have not been excavated to bedrock (J.D. Evans 1971: 98-9). He argued that the resolution of the published information did not allow the rate of settlement and population growth to be estimated (Whitelaw 1992: 226-7). Regardless of the rhythm and exact chronology of growth, however, it is safe to conclude from J.D. Evans' explorations that the settlement *did* expand between the earliest Aceramic and the LN, by which time the human community of Knossos had exceeded the size that could function on an egalitarian basis (Table 3:2).

Table 3:2 Estimates of settlement area and population range (after Broodbank 1992: 43, table 1; estimates for MN very approximate).

Phase	Settlement area (ha)	Population range
Aceramic	0.25	25-50
ENI	2.00	200-400
ENII	3.00	300-600
MN	[4.00]	[400-800]
LN	5.00	500-1000

The internal organisation of this growing settlement is far from clear. Throughout, there are indications of both built-up and open areas, but the small exposures for the earliest phases have uncovered fragmentary architectural traces, not easily interpreted. An important issue is the

extent to which production and consumption were primarily conducted by small 'households' or on a more collective basis. The evidence from Knossos could be accommodated to the suggestion, based largely on evidence from the northern mainland, that household isolation increased through the Neolithic in Greece (Halstead 1995c): free-standing rectangular houses are known from MN Knossos, while at least some consumption activity took place in open 'communal' spaces in Aceramic and ENI. On the other hand, standing walls indicate some substantial buildings even in the Aceramic, suggesting some physical and symbolic emphasis on dwellings (cf. Kotsakis 1999). The evidence as yet is ambiguous, although the occurrence of house models from ENII (Tomkins *in press b*) perhaps hints at growing concern with the household. The social tensions accompanying settlement growth, therefore, may well have been exacerbated by the contradiction between collective and household identity and interests. In this context, it is worth noting that the relatively large and complex Neolithic houses found by A. Evans, and dating to the end of the Neolithic might possibly resemble the emergence of larger domestic households of Mesopotamia (e.g., Pollock 117-23), incorporating dependents and workers other than close kin.

3.1.1.3 *Isolation?*

Conflicting views have also been expressed in terms of the position of Neolithic Knossos in the Cretan and southern Aegean landscape. J.D. Evans noted the uniqueness of the site within Crete, certainly for the Aceramic-ENI periods (Strata X-V, or Aceramic to early LN in mainland terms) (J.D. Evans 1968: 276). Since the 1960s the situation has not changed. Sites from this horizon are still absent, and claims to the contrary (i.e. for the sites of Gerani, Pelekita, Magasa, Aghios Ioannis, and Lera) have not been 'fully substantiated', as pointed out by Tomkins *et al. (in press)*. The same researchers, however, argue that other sites must have existed in the EN – without, however, specifying which part of the EN is meant – in the Herakleio basin and the Bay of Mirabello (Tomkins and Day 2001; Tomkins *et al. in press*), based on macro- and microscopic analysis of the pottery from this period. These findings reinforce earlier suggestions that the lack of known early Neolithic sites – despite the increasing numbers of intensive surveys – may be attributable to taphonomic factors (loss through erosion and/or burial through alluviation) rather than true absence. The existence of sites is more satisfactorily documented for later periods, especially LN/FN, both from excavations and surface surveys. This isolation is also manifested, according to the excavator and others, in the lack of 'imported' artefacts and raw materials, with the exception of obsidian. Moreover, as Broodbank points out, obsidian is so rare in Neolithic deposits as to suggest that procurement expeditions were sporadic (Broodbank 1992: 48).

At present, the most economical conclusion is that Knossos existed in a sparsely inhabited landscape until the end of EN, as already pointed out by Cherry (1990: 161) and Broodbank (1992: 40). In later phases, it became part of a more densely inhabited landscape, including habitation in the uplands and systematic use of caves and rockshelters. This pattern attested in the southern Aegean as a whole in the 4th millennium BC, suggests the ability of human communities to exploit marginal landscapes (i.e., small islands, uplands, etc.) more efficiently and has been linked by some to the management of animals for secondary products (see discussion in Chapter 1).

3.1.1.4 *Change and innovation*

According to J.D. Evans, change at Neolithic Knossos was *slow* and *gradual* and the community was characterised by conservatism: raw materials used he considered to have been locally available with the exception of obsidian (J.D. Evans 1964: 231, 233; 1968: 270; 1971: 115). He saw, however, occasional signs of innovations and outside contacts: spinning and weaving equipment and a number of new pottery shapes, which could be characterised as serving/consumption vessels – chalices, fruitstands, spouted vessels and carinated bowls – were introduced towards the end of ENII and were interpreted as a sign of 'quickening intercourse with other parts of the Aegean' (J.D. Evans 1971: 115, 109 and footnote 2).

Gradual change was also visible in animal husbandry, in relative frequencies of managed taxa, with cattle becoming progressively more abundant, although he refrained from attributing the change to environmental change or human management (J.D. Evans 1968: 270). Broodbank was bolder in his interpretation of the faunal evidence: he saw the increase in number of cattle remains, combined with the preponderance of cattle among zoomorphic figurines, as reflecting their symbolic significance as a possession and 'prestige food for conspicuous on-site butchery, consumption and discard' (Broodbank 1992: 62).

3.1.1.5 *Summary*

Neolithic Knossos has generated a considerable amount of debate, including a number of topics relevant to the present study: the introduction of farming; changes in size of the community with obvious implications for access to land for arable and pastoral production; isolation and the introduction of new technologies, such as management for secondary products. All of the above are immediately relevant to the study of faunal remains.

3.3.2 The Bronze Age

3.1.1.6 *Introduction*

The Bronze Age on Crete is marked by several archaeologically manifested changes in social and economic structures. Changes observable at Knossos include: the exceptionally large size of the settlement compared to contemporary sites, already in the Prepalatial period, and its certainly urban character in the Palatial phases; the creation of a public/elite area at the core of the settlement, on the Kephala hill, characterised by elaborate monumental architecture, which started developing in the Old Palace period, if not earlier according to a formal plan; the particular character of this architectural complex, which incorporated storage and artisanal areas, ritual and arguably domestic areas for a ruling group; the development of a palatial 'administration' employing a variety of writing and sealing systems; finally, the existence of Knossos within a complex network of settlements, both within and without the island, characterised by more intensive exchange of goods, technologies and ideologies. The following sections review the evidence for these changes in chronological order.

3.1.1.7 *The Prepalatial period*

Although excavated EM settlements are few, a settlement hierarchy is apparent, at least in terms of relative size, as the greater extent of Knossos and other later palatial centres is already evident in the Prepalatial period (Table 3:3).

Table 3:3 Sizes of EM settlements on Crete (after Whitelaw 1983, fig. 73).

Site	Probable extent (in ha.)	Estimated number of houses	Estimated Population
Myrtos-*Phournou Koryphi*	0.09	5-6	25-30
Mochlos	0.83	55	220-330
Phaistos	1.13	75	300-450
Mallia	2.58	170	690-1030
Knossos	4.85	320	1290-1940

The introduction of the olive and vine (Renfrew 1972) and of novel animal management techniques (Sherratt 1981; 1983) have been used to explain the concentration of human population in a small number of such large settlements (Watrous 1994: 704). There is no consensus about the causes of this change, however, nor of the rise of social ranking within settlements inferred from the appearance of more formal disposal areas for the dead in the Mesara and on the north coast (e.g., Soles 1988; Wilson 1994: 44). In terms of portable material culture, pottery styles become more elaborate and are more widely circulated within the island (e.g., Whitelaw *et al.* 1997; Wilson and Day 1994) and there is growing evidence for *metallurgy*

(e.g., Branigan 1974; Nakou 1995). A range of new imported artefact types, often locally imitated (e.g., Broodbank 2000: 278) implies increased off-island contacts mostly with the Cyclades from EMI onwards, at some north coast sites like Aghia Photia (e.g., Day *et al.* 1998) and Poros (e.g., Dimopoulou 1997), and from EMIIA at Knossos (e.g., Wilson 1994: 42).

The EMI period at Knossos, although poorly known from stratified deposits (Table 3:4), is characterised by a strong discontinuity in pottery shapes and wares – best attested in the Palace Well deposit – from the latest Neolithic, tentatively attributed by Hood to the influx of settlers (Hood 1990a). Although more recently researchers have refrained from interpreting the gap in these terms (see summary on this topic in Wilson and Day 2000: 54), Wilson and Day are also categorical in their assessment of the degree of change between the two pottery traditions (Wilson and Day 2000: 54). More importantly, the Palace Well deposit is also thought to represent a special event of communal consumption of pottery vessels, drink and possibly food, signifying the intensification of social competition through *feasting* (Wilson and Day 2000: 61-2).

Table 3:4 Stratified EM deposits from excavations at Knossos (data from Wilson 1994: 25-26).

Period	Location	Type of deposit	Associated architecture	Excavator	Date of excavation
EMIA	Palace Well	Fill	No	S. Hood	1958
EMIA	North Lustral Basin	No data	No	S. Hood	1987
EMIB	Trench FF (Level 4)	Fill (burnt)	No	J.D. Evans	1969
EMIB	Throne Room	No data	No	S. Hood	1987
EMIB	North-West Quarter	No data	No	S. Hood	1987
EMIIA	West Court House	Floors and fills	Yes	J.D. Evans	1969
EMIIA	Royal Road South	Floors	Yes	P. Warren	1972
EMIIB	South Front Early Houses	Floors	No	S. Hood	1960
EMII-III	Royal Road North	Fill and floors	Uncertain	S. Hood	1957
EMIII	South Front Early Houses	Floors and fills	No	S. Hood	1960

For later phases, tests in various areas under the later palace have provided evidence for some large-scale re-organisation in EMIIA (Wilson 1994: 36), including building, destruction and infilling of the West Court House, followed by levelling and terrace building in EMIII, possibly to create open areas and/or allow for a new layout of structures in the centre of the settlement (Wilson 1994: 44). Finally, formalised mortuary structures, like the Mesara round tombs (Xanthoudides 1924), are not known from the immediate area of Knossos at this period and the organisation of the settlement is poorly understood. It is difficult therefore to define the nature, let alone causes, of socio-economic change at EM Knossos. There are tantalising hints, however, of the existence of social competition (Wilson and Day 2000) and perhaps of central authority (Wilson 1994: 42) at a site which, in size, had already outstripped contemporary settlements on Crete and far exceeded the limits of egalitarian organisation (Whitelaw 1983).

3.1.1.8 *The Palatial period*

The immediate Prepalatial period (MMIA) is very poorly known at Knossos and, as yet, there is no consensus about the socio-economic structures which preceded the palaces (e.g., Cherry 1983; 1986). Moreover, the Old Palace period at Knossos is essentially known from material redeposited after thorough clearance and re-construction (MacGillivray 1994: 48), making it difficult to assess its precise character and the degree of palatial control over society. As for faunal remains, individual sub-phases (Old, New and Final Palatial) are not at present adequately represented in terms of sample sizes, such as to allow a detailed diachronic analysis. Accordingly, the present section deals with the Palatial period as a whole.

At the time the first palace is built, Knossos witnesses a dramatic change in the size of the settlement (Table 3:5) and in the spatial organisation and architectural character of what Whitelaw has referred to as 'the public/elite core' (Whitelaw 2001). Although the exact size and configuration of the first palace are rather obscure (Cadogan 1987), we have enough evidence to suggest that essentially it performed similar functions to the later palaces, which are archaeologically better understood, while textual evidence for the Final Palatial period allows a more nuanced understanding of the workings of the palatial administration.

Table 3:5 Estimated size of the settlement and population of Knossos in the BA (data from Driessen 2001: 63; Whitelaw 1983, fig. 73; Whitelaw 2001: 27).

Period	Probable extent (in ha.)	Estimated number of houses	Estimated Population
Prepalatial	4.85	320	1290-1940
Protopalatial	45	2800-3000	11000-18000
Neopalatial	75	No data	14000-18000

The monumental character of the central palatial complex is evidenced in the use of ashlar masonry, planned layout and formal approaches, such as the Royal Road, already in existence in the Old Palace period (e.g., MacGillivray 1994). Further elaboration included the possible use of bright colours, crystalline gypsum façades and, in the Neopalatial and Final palatial periods, an extensive figural iconographic programme (Rehak and Younger 2001: 411). The existence of the palace implies a ruling elite capable of pooling resources and a workforce, which included skilled craftsmen, but also symbolises the centrality of the palace in the ideological life of the community and perhaps of a wider region.

Accumulation of goods and bureaucratic monitoring appear to have been major concerns of the Minoan palaces (Knappett and Schoep 2000). This is indicated by the existence of extensive storage areas within the palace, possibly from the Old Palace period (e.g., Watrous 2001: 204),

and by the appearance of writing together with a sophisticated accounting system in the broad horizon of emerging palaces (Schoep 1999: 268). Although the earlier scripts remain undeciphered, there is some evidence to suggest that at least *Knossian* administrative documents recorded goods, most importantly wine, oil and grain, which were mobilised *from the hinterland*, while indirect evidence suggests that sheep may also have been monitored (Schoep 2001: 91). This bureaucratic system sees its apotheosis in the Final Palatial period, when it is used exclusively for administrative purposes, so far as our evidence to-date suggests (Bennet 1988: 509), and centres on the close monitoring of selected areas of the economy (e.g., Halstead 1992d; 1998-9: 150), of which sheep wool flocks and plough-oxen teams, already mentioned in Chapter 1, are most relevant for the present study. Administrative documents also inform us of the existence of specialists, involved in the production of prestige artefacts for the palace – e.g., horners mentioned in tablet Un 1482 from Pylos (Killen 2004).

Moreover, palaces appear to have eventually dominated the ideological life of the communities, as suggested by the centralisation of peak sanctuary cult in the Neopalatial period (Peatfield 1992: 61) and by the widespread use of similar, even identical, cultic equipment and shared iconography both on portable artefacts and buildings across the island. All these features become widespread throughout the island in the Palatial period creating a koine of architectural forms (e.g., Cherry 1986), administrative methods (e.g., Schoep 2001: 87), iconography and religion (e.g., Peatfield 1992: 61).

For the purposes of the present study, attention should be drawn to the following implications of the preceding discussion. First, the ability of the Palace to collect and store bulk agricultural produce (wheat and oil), to undertake large-scale monumental building and to employ a dependent workforce, implies the availability of and access to surplus produce, whether grown on palatial estates or acquired through taxation (e.g., de Fidio 1992; Halstead 1998-9; Killen 1998). It is unclear at present whether such structures were present already in the Protopalatial period and whether they developed, or remained unchanged through the Neopalatial and Final Palatial periods. What is most important for the present study is the observation that production of surplus grain would have required the use of plough-oxen (e.g., Halstead 1995b), which is indeed well attested in the latest, Final Palatial period administrative documents (e.g., Killen 1993b; Palaima 1992). Secondly, the increased population size at Knossos in the Palatial period implies pressure on arable land in the vicinity of the settlement and possibly an extension of land holding and control to a wider geographical area. Finally, the diversity of Minoan cooking equipment (Borgna 1997: 205) and the quantity and elaboration of pottery vessels destined for serving and consumption, coupled with the widespread provision of formalised reception or gathering areas within the palace (e.g., the pier-and-door partitioned room complexes and open

courts), suggest an important role for the consumption of food and drink in a palatial context (Hamilakis 1996b; Moody 1987b; Wright 1996).

3.4 The archaeological context of the faunal remains

3.4.1 Introduction

In order to provide a better understanding of the character of deposits from which bone groups were derived, and thus a better understanding of the character of the faunal assemblage, this section summarises archaeological information provided by excavators, in the form of published reports or unpublished manuscripts. The general areas of the various excavations are marked on Figure 3:1, while a more detailed plan of J.D. Evans' trenches is provided in Figure 3:2 below. Deposits are presented in chronological order and particular contextual aspects are highlighted which bear relevance to the results yielded by the analysis of the faunal remains.

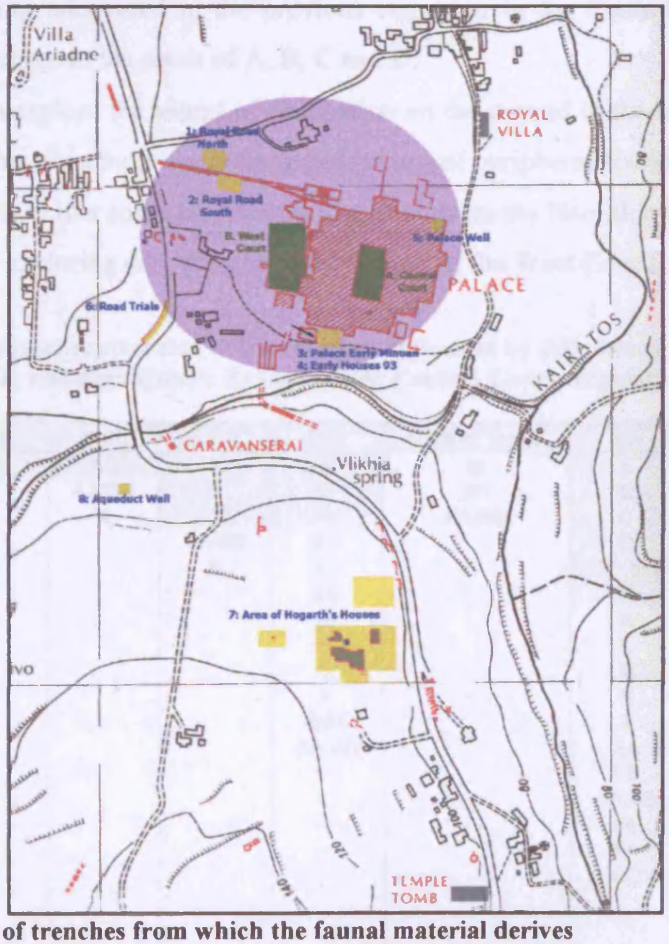


Figure 3:1 Location of trenches from which the faunal material derives (green: major areas of Neolithic deposits; yellow: major BA deposits; grey circle: area defined by Whitelaw as the public/elite core of the settlement).

3.4.2 Neolithic – J.D. Evans' campaigns: 1957-60 and 1969-7

J.D. Evans' first campaign (1957-60) constituted the first extensive and systematic investigation of Neolithic occupation at Knossos. Four 5x5m squares (A to D) and a small extension to the east (trench F), were excavated in the northern part of the Central Court of the Palace, underneath the BA pavement, while a narrow (1x3.5m) trench (XY) was opened to the north of the Central Court. In 1969, J.D. Evans returned to Knossos. His aims, detailed in his 1971 preliminary report and informed by the previous campaign, were fourfold (J.D. Evans 1971: 95 ff.) (for a list of trenches and dates of deposits unearthed in each, see Table 3:6 and Figure 3:2):

- First, by exposing a larger area, to explore whether differences existed between different areas of the site; for this purpose several trenches were opened in the West Court;
- Secondly, 'to obtain a better idea of the general character and interrelations of the buildings' (J.D. Evans 1971: 96); with this in mind, he exposed a greater area of the MN building uncovered in the previous campaign in the Central Court by opening further trenches to the south of A, B, C and D;
- Thirdly, to explore the extent of occupation on the mound in the successive phases of the Neolithic; this was to be achieved by means of peripheral soundings;
- Fourthly, to 'throw some light on the transition from the Neolithic to the Early Minoan period' by exploring deposits below the paving of the West Court.

Table 3:6 Ceramic phases represented in the trenches excavated by J.D. Evans (highlighted: Evans1; non-highlighted: Evans2; bold: Central Court; regular: West Court; italics: other areas).

Aceramic	ENIa	ENIb	ENIc	ENII	EN/MN Trans	MN	LN	EMII
AC	**AC**	**AC**	**A**	**A**	**M**	**A**	A	AA
X	X	AA/BB	**C**	**C**	*ZH*	**B**	B	BB
ZE		**X**	***XY***	***XY***	AA/BB	C	C	1=DD
			AA/BB	*ZH*		D	D	2=CC
			X	*ZG*		**BD ext**	F	
				EE		***XY***	**BD ext**	
				M		K	K	
				P		L	L	
				Q		**M**	**M**	
				R		**N**	**N**	
				RST		T	P	
				AA/BB		AA	Q	
						BB	R	
						AA/BB	S	
						EE	T	
						FF	X	
						GG	AA	
							BB	
							CC	
							EE	
							FF	

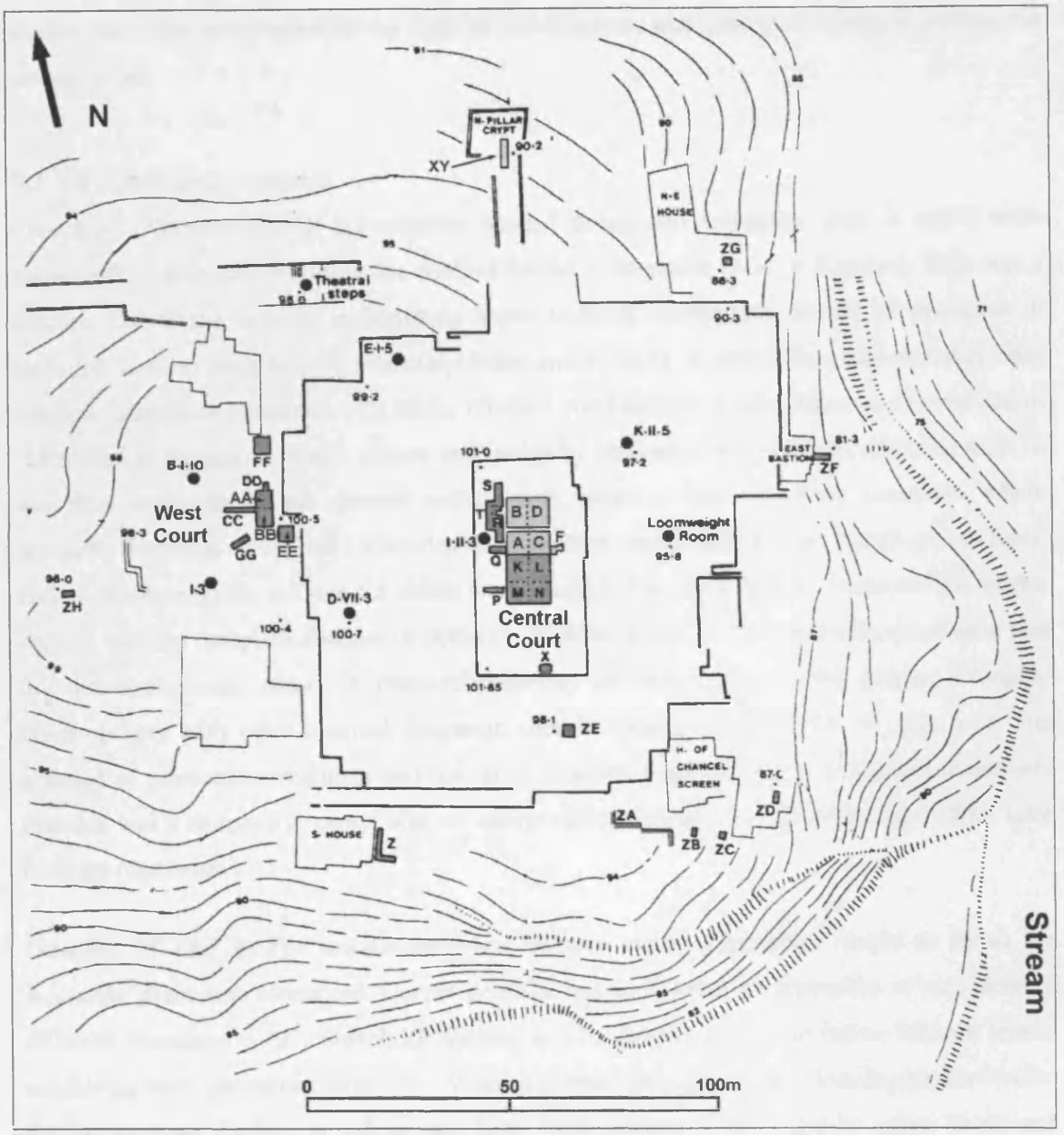


Figure 3:2 J.D. Evans campaigns trench locations
(grey: 1957-60 campaign; dark grey: 1969-70 campaign).

Neither campaign was fully published, although the excavator has completed the analysis of the stratigraphy and pottery from both campaigns. The first campaign was presented in relatively greater detail in an extended article in the *Annual of the British School at Athens* (J.D. Evans 1964), followed by a second article, containing specialists' reports, in the same journal (Warren *et al.* 1968). The second campaign was treated in a summary fashion in the *Proceedings of the Prehistoric Society* (J.D. Evans 1971) and a bigger synthesis appeared in 1994 (J.D. Evans 1994). Limited information is also provided in preliminary reports in the British School's *Archaeological Reports* (*AR*) and in Tomkins' unpublished PhD thesis, as a background to his ceramic analysis (Tomkins 2001). The following brief presentation of the excavated deposits

should therefore be assessed in the light of the literature available at the time of writing the present work.

3.1.1.9 *Aceramic deposits*

Trench AC (Stratum X): Of the trenches opened during this campaign, only A and C were excavated to bedrock, revealing the earliest known occupation level at Knossos. This was a shallow (20-40cm) deposit, immediately above bedrock, completely devoid of structures. It included features such as pits, post/stake-holes and hollows in which fires had probably been kindled. Some pits contained only earth, others a combination of ash, charcoal, charred grains (identified as hexaploid wheat, emmer and barley by Helbaek), animal bones and bone tools. It was thus interpreted as an open-air activity area, possibly with temporary structures, where primarily domestic refuse had accumulated. In addition, seven child burials (ranging from foetal and/or newborn to ca. 6-7 yrs old child) were located. The most striking characteristic of this deposit was the complete absence of pottery, which led Evans to the inevitable conclusion that this was an Aceramic phase. ^{14}C dates subsequently confirmed an early date, making it roughly contemporary with other claimed Aceramic sites in Greece (Perlès 2001: 91, fig. 5.5). The absence of permanent structures and the rarity of small finds led Evans to suggest tentatively that this was a temporary 'camp' site, an interpretation that he rejected in the light of his later findings (see below).

Trenches ZE and X: The second campaign revealed rather unexpected results as far as the Aceramic phase was concerned. Deeper deposits had survived in two trenches of considerably different character to AC. Trench ZE yielded a 1.2m deep deposit, just below Minoan levels, containing more permanent structures. Mudbricks were arranged in lines forming parallel walls; the bricks were distinct in colour and form from Minoan ones found in upper levels and identical to those found in Trench AC in the later Strata IX and VIII (see below, section 3.1.1.10), although those in ZE were unfired (J.D. Evans 1971: 101). The discovery in trench ZE prompted the expansion of the investigation in an area to its north, which was named trench X and yielded even more surprising results. Below LN and ENI levels, a 2m deep deposit of Aceramic had survived, albeit cut in several places by pits dug from above. Although devoid of pottery, it contained two figurines made of baked clay. Walls made up of a mixture of stone (often re-used querns), unfired bricks or 'bricky material' and clay were found at four different levels, closely resembling those in Strata IX and VIII of Trench AC. J.D. Evans considered these deposits to be contemporary with, if not earlier than, Stratum X in AC (J.D. Evans 1971: 102-3). The results of the excavation (relative heights of bedrock revealed under anthropogenic deposits, as well as distribution of features and finds), combined with topographic survey, led the excavator to the following conclusions: the original habitation was concentrated in a small

area (ca. 0.25 ha) on the highest point of the Kephala hill (Trenches X and ZE), with an area further to the north (Trench AC) dedicated to a variety of outdoor activities, such as food preparation and burial of the younger members of the community (J.D. Evans 1971: 103).

3.1.1.10 *Early Neolithic deposits*

3.1.1.10.1 *Tomkins' ENIa*

*Trench AC (Stratum IX):*A 0.30-1m thick deposit containing largely 'variegated debris of fired mudbrick' preserved part of a structure (House E) whose wall foundations were made up mainly of mudbricks with variable amounts of stones, including querns and mortars. Part of a roughly rectangular room was revealed, which had been rebuilt and remodelled several times, and traces of floors were also preserved. The superstructure also probably consisted of mudbricks and partly, possibly, of pisé, while there is evidence that the roof was made of brushwood and clay. A mudbrick bearing the hoof imprint of a ruminant has been stored at the Stratigraphic Museum and on inspection seemed to be free of ceramic/bone inclusions. The excavator observed that the floor within the house was almost devoid of any finds. After the collapse of the building, several pits filled with ash had been cut from upper levels into floor and walls of the house. Pottery was rare, heavily fragmented and hardly any joins were possible, suggesting that this material had been originally deposited elsewhere (Tomkins 2001: 485).

Trench AC (Stratum VIII): The deposit varied in thickness between 0.20-0.30m over most of the area, but was preserved to greater depth in the northern part (0.90m). It contained mostly debris of broken and disintegrating mudbricks and habitation debris. One structure only was identified in square A (House D), which was very poorly preserved: only fragments of two walls and of the mud floor had survived. Other features identified were remains of two ovens and a pit containing ash, all of which had probably been in use contemporaneously. In area C of the trench, after the destruction of House D, two pits were dug into the destruction deposits: Pit A, which contained ash, two stone figurines, and pottery fragments from some of which a bowl was reconstructed; and Pit B, which contained sherds and one unbroken pot. This was the earliest example of such pits, cut into the collapsed debris/fill of a house and containing complete vessels.

Trench X: Phase ENIa was represented in Trench X by four pits, cut into the earlier Aceramic deposit. Pits A, B and C – the latter only partially excavated – were cut in the bottom of a larger one dubbed the 'Great Pit' and, together with the lower fill of the latter, constitute level X18. Pits A and B were regular (diam. 1m, depth ca. 1m) in shape and the 'Great Pit' more irregular. Pit A contained one sherd and obsidian and Pit B contained bone, obsidian, flint and some

pottery (Tomkins 2001: 494, based on excavation notebooks). No interpretations have as yet been put forward concerning the function of these pits.

3.1.1.10.2 *Tomkins' ENIb*

This period is marked by a change in building technique, encountered throughout the soundings made in both campaigns. Use of mudbrick –raw or fired – ceases and is replaced by packed mud (pisé) on a foundation of stones, including unworked stones and lumps of the local soft limestone, *kouskouras,* and often re-used querns and mortars (J.D. Evans 1964: 150-57.).

Trenches A and C (Stratum VII): The thickness of the deposit varied between 0.40 and 1.00m and contained the remains of a fairly well preserved structure, House C. This consisted of two adjoining rectangular rooms, east and west, which preserved several features. In the eastern room, a burnt area, where presumably fires had been lit, and small circular depressions with smoothed clay surfaces with signs of burning inside and around them, some overlapping implying repairs, suggest that this may have been an area where food was prepared. The western room, whose floor was covered with a layer of ash, contained a stone-lined feature with its clay floor burnt brown and in which lay some fragments of a clay pot, suggestive of a hearth, although J.D. Evans also suggests the possibility that this may have been a cupboard for storage (J.D. Evans 1964: 153). Small circular depressions of the type encountered in the adjoining room were also found here, but bore no sign of burning. They also existed under the first floor of both rooms and in this case, almost all bore traces of burning. External areas preserved cobbled surfaces to the north of both rooms, as well as to the south and west, at the levels of the two floors. Additionally, part of a structure later than House C was uncovered in the NW end of the trench, while, in the collapse levels of House C, bones of a small animal were found, associated with fragments of a smashed pot. The few small finds discovered were the usually encountered types, bone and stone (ground and chipped) implements, figurines, etc..

Trenches A-C (Stratum VI): The thickness of this deposit varied between 0.50 and 1.20m. No recognisable structure was revealed in this stratum, only disjointed features, such as irregular patches of cobble paving and larger stones in line – which may originally have belonged to walls. Two small circular depressions were also found here, of the type described in Stratum VII. Another interesting feature was a flat rectangular patch of smoothed clay (25x15cm), fired brown, which J.D. Evans interpreted as a platform (J.D. Evans 1971: 155). The finds included some complete and restorable pots, stone objects, several bone tools, and chipped stone.

Trench AA/BB: In this area, 2m deep ENIb deposits had accumulated immediately above bedrock. No permanent structures were revealed, only fragments of features such as cobbled surfaces and part of a stone floor, while there was evidence also for the 'new' pisé and stone

technique. J.D. Evans interpreted this as an area on the edge of the habitation where refuse had accumulated.

Trench X (Levels 13-17): Traces of permanent structures were absent in this sounding. Only thin deposits from this phase were revealed, similar in composition to other fill/rubbish deposits around the site. This deposit filled the upper part of the 'Great Pit' (see Section 3.1.1.10), and sealed all the area over and around the pit (Tomkins 2001: 502).

3.1.1.10.3 *Tomkins' ENIc*

Trenches A and C (Stratum V): The thickness of this stratum was 0.70-1.00m. The upper levels preserved only patches of walls, floors, and rows of stones of uncertain function. In the NW part of the trench were found fragments of corners of wall foundations. Connected remains were only revealed near the bottom of the deposit and were associated with compartments defined by rows of small stones, whose function was not clear. Other features found were hollows in various levels and parts of the trench, while the usual range of small finds were recovered – several figurines, stone and clay objects and bone tools.

Trenches AA/BB and X: No contextual information is presently available for levels of this date from trenches AA/BB and X. Tomkins did not include a discussion of the relevant levels from these trenches in his doctoral study, while J.D. Evans in his preliminary report (J.D. Evans 1971) does not make this chronological sub-division.

3.1.1.10.4 *ENII*

Trench AC (Stratum IV): This 1.00 to 1.50m thick deposit consisted of many thin layers of occupation, but the structural remains it contained were very scarce and too fragmentary to establish any functional relationships between them. Moreover, they appeared to be too flimsy to constitute parts of a house and this, in combination with a number of other features – hearths, clay structures, patches of pebble pavement and shallow pits (J.D. Evans 1964: 164) – suggested to the excavator that this area in ENII was an external activity area and the layers excavated represented 'undifferentiated refuse deposit[s]' (J.D. Evans 1973: 136).

Sounding XY: Three superimposed buildings were uncovered, each retaining the size and orientation of the earlier one, the earliest being the best preserved. From this phase, a stone structure was preserved in the corner, enclosing remains of a large pot, while to the north of the wall, presumably in an external area, a concentration of animal bones was revealed.

Trenches AA/BB: 2.50 to 3.00m thick deposits were excavated in this area containing parts of complex structures attributable to three successive architectural phases. They were composed of

a series of small rooms with often more than one floor level and contained hollows like those described in Section 3.1.1.10.2. They had been altered on several occasions (walls mended, doorways blocked up, etc.). After each abandonment episode, it appears that the buildings were filled in with soil and occasionally rubble, on top of which the subsequent building was immediately built, as can be deduced by the absence of any intervening layers accumulating between successive constructions.

3.1.1.11 *Middle Neolithic deposits*

Trenches A-C (Stratum IIIB): The 1.50m thick deposit mainly represented occupation refuse; walls and patches of pebbled surfaces were preserved in fragmentary state, but features were unconnected. The walls probably belonged to enclosures rather than houses, to judge from their flimsy construction, and the pebbled surfaces contained several bones and probably represented external areas. Another 'pottery pit' was discovered containing whole crushed pots (J.D. Evans 1964: 172, 174).

Trenches B-D (Stratum IIIB): Remains of two structures were revealed: a rectangular room (4x4m) of House A with wide (1m) stone wall foundations, preserved in places to a height of 1m. Its floor and walls were covered with clay and it contained a number of features: in one corner a clay-built platform raised 20cm from the floor and defined by stones; a fire hollow in the centre of the room; and, finally, two features interpreted by the excavator as 'cupboards'. Apart from two pots, very little else was found on the floor. Outside the house were thick deposits of occupation debris. Subsequent to its collapse/infilling, another 'pottery pit' – with crushed pots was cut into the rubble/fill (J.D. Evans 1964: 172, 174).

Trenches A-C (Stratum IIIA): Few architectural features survived in this area. To the SE, the corner of a massive structure was revealed, which was traced further in Trench F, while a patch of pebble paving and a pebble bench had also survived outside the building (J.D. Evans 1964: 174).

Trenches B-D (Stratum IIIA): House B, slightly later than House A, was uncovered in this area. Its walls had survived to a height of ca. 1m. Parts of two rooms were revealed within the excavated area while a third possibly represented an enclosed area by the side of the house. In the exterior a patch of pebble paving had also been preserved (J.D. Evans 1964: 176). Further parts of this building were revealed in the second campaign (see below in discussion of trenches R, S, T).

Trenches R, S and T: These trenches were excavated with the explicit aim of investigating further House B discovered in area B-D in the first campaign. This exploration revealed that House B resembled in form the agglutinative house in trenches K/L/N (see below) and Arthur Evans' Neolithic Houses (J.D. Evans 1971: 98).

Trenches K, L, M, N: The structures uncovered here greatly resembled the Neolithic houses discovered by Arthur Evans in the CC, being agglomerations of small rooms. One of these contained a large number of objects interpreted as spindle-whorls, loom-weights and 'shuttles' and was thus thought by J.D. Evans to represent an area where spinning and weaving took place, or where at least this equipment was stored (J.D. Evans 1971: 111). Confusingly, J.D. Evans says this building was built in MN, but continued in use until early LN, as early LN material is found down to floor level in most rooms (J.D. Evans 1971: 97).

Trenches AA/BB and EE: These also revealed the remains of a structure comparable to the complex houses mentioned above, while the walls of the structure in AA/BB exhibited a number of repairs (J.D. Evans 1971: 111).

3.1.1.11.1 *Late Neolithic deposits*

Trenches A-D (Stratum II): Although the thickness of deposit here was considerable (1.00-1.30m) remains of structures were patchy, with two corners of walls, unrelated to each, one in trenches A and B and another in D, whose north-eastern part is likely to have collapsed down the hill (J.D. Evans 1964: 183-4). The excavator, however, reports 'much evidence of intense human activity', which unfortunately is not specified (J.D. Evans 1964: 183).

Trenches A-D (Stratum I): Some architectural remains were discovered in trenches BD, but the deposits appear to have been mostly fills for levelling purposes after the buildings had collapsed (J.D. Evans 1994: 16).

Trenches AA/BB, EE and FF: The deposits dating to this period in the West Court did not yield any remains attributable to houses. A number of fragmentary features uncovered were described by J.D. Evans as 'flimsy partitions...which seem to have been built to delimit yards or working areas', of a type also encountered in earlier deposits (J.D. Evans 1971: 113). The latest deposits in FF were probably midden deposits.

3.1.1.12 *Summary*

The following points can be made from the above brief presentation of the find contexts of the faunal assemblages analysed here. From most phases a combination of open and closed,

habitation and refuse disposal areas are represented in the deposits. Where samples are large enough, this should allow a comparison between material from these two broad types of context in order to explore possible differences both in bone preservation, and in the spatial organisation of bone disposal. A number of features uncovered can be plausibly interpreted as food preparation facilities (e.g., hearths, cooking holes), offering the opportunity for more detailed contextual analysis, but unfortunately, this information was not available in time to be used in the present analysis.

3.4.3 Bronze Age

Excavations from which Bronze Age deposits were available for study are presented in Table 3:7 and Table 3:8. Compared with the Neolithic, the BA ceramic sequence is well established and understood. Rapid development and substitution of ceramic styles provide a finer chronology, while intensified contacts between Knossos and other sites, both within the island and overseas, from EM onwards mean that the problems of Neolithic pottery phases are not applicable to the BA.

Table 3:7 Locations and map references of BA excavations

Area	Code	Excavator	KS Plan	KP Plan	Figure 3:1
Royal Road North	RRN	Hood	215	N/A	1
Royal Road South	RRS	Hood	214	N/A	2
Palace Early Minoan	PEM	Hood	N/A	Near 2	3
Early Houses 93	EH93	Momigliano and Wilson	N/A	Near 2 and 12	4
Palace Well	PW	Hood	N/A	183	5
Road Trials	RT	Hood	206	N/A	6
Hogarth's Houses	HH	Hood	297	N/A	7
Aqueduct Well	AQW	Hood	290	N/A	8

Table 3:8 Spatial distribution of BA deposits by ceramic phase (only contexts relevant to the present study are included).

PP: EMI	PP: EMII	PP: EMIII	PP: MMIA	OP: MMIB-MMIIA	NPUndif	NP: LMIA	NP: LMIB	NP: LMIA/B	FP: LMII-IIIB
PW	PEM	RR	RRS	RT	HH	HH	HH	RR	RR
	EH93	EH93		EH93	RR	RR	RR	HH	HH
	WCH	PEM		RR	RT				
				AQW					
				HH					

3.1.1.13 *Prepalatial deposits*

The Prepalatial deposits analysed were excavated by J.D. Evans (WCH), Hood (PW, RRN, RRS and PEM) and Momigliano and Wilson (EH93). They cover the whole of the EM and MMIA, the last ceramic phase before the construction of the first palace at Knossos. All ceramic phases are not equally well represented in terms of abundance of faunal remains. Nevertheless, they constitute to-date the largest analysed faunal assemblages from the entirety of the island, as well as providing the most complete, continuous sequence. In the text that follows, the various

deposits/trenches, from which faunal material was derived, are presented in chronological order, together with any contextual information available.

3.1.1.13.1 *EMIA: Palace Well*

References in AR 1959 for 1958: 18; AR 1960 for 1959-60: 25; Hood in prep.[3]

The Palace Well, a chance discovery located in the NE area of the later Minoan Palace, was excavated in two seasons in 1958-9. It was interpreted by the excavator (Hood) as a well in use during EMIA, which, sometime before the end of this phase, was abandoned and filled with debris from a fire which destroyed all or part of the settlement (Hood 1990: 371). The well was partly cut into earlier Neolithic deposits and partly into natural bedrock, to a depth of 17.20m from the present surface. In terms of its stratigraphy, the fill consisted of three major stratigraphic units (information from Hood *in prep.*):

1. A 3m deep unit containing a mixture of LM and Neolithic pottery (levels 1-2) (the material from these levels was not included in the present study):
2. A 11.20m 'soft ashy' unit incorporating fire destruction debris with pottery dating to EMIA and some admixture in the upper levels of Neolithic (presumably fallen from the upper part cut into Neolithic deposits) (levels 3-23);
3. Finally, a unit whose upper part consisted of sterile clay from which pottery was absent, 'a deposit that formed below the ancient water level' according to the excavator, while in its lower part the clay was mixed with lumps of natural bedrock (levels 24-25).

Of importance for the present study are the conclusions drawn by the excavator concerning the character of unit (2), from which most of the bones were recovered. Hood describes it as follows: 'the fill consisted of stones with layers of wood ash and lumps of fire-hardened clay, evidently debris from burnt structures. Much of the pottery had been discoloured by fire, and consequently a number of fragments which joined were of quite different colours. Minor distinctions were noted in the character of the fill at various depths... The Well, however, had evidently been filled in only a single operation, and the pottery throughout was uniform in character. Joining fragments of the same vases were found dispersed at different levels in the fill. Fragments of the lid 124, for instance, came from depths of about 9, 11, 12 and 13m' (Hood *in prep.*). In a recent study, Wilson and Day have raised the possibility that PW may have been infilled with debris from 'a drinking/feasting ceremony' – in view of the range of vessel shapes represented, setting it apart from deposits of the same phase at Knossos and other sites on the island (Wilson and Day 2000: 53). They propose that this ceremony, which 'involved the

[3] Because of the brief nature of preliminary reports, references are presented in the beginning of each section, rather than in the text itself.

consumption of drink and food' may have been one manifestation of social change at the site (Wilson and Day 2000: 62).

Both interpretations imply that the fill contains material from a single event, with the latter suggesting the possibility that consumption of food is represented by these remains. The faunal evidence should be able to contribute to the evaluation of interpretations put forward concerning this deposit.

3.1.1.13.2 *EMIIA-III: Royal Road North*

References in AR 1959 for 1958: 18; AR 1960 for 1959-60: 25; Hood in prep.

EMII-III levels were excavated in 1961 in an area 2.75x2.45x2m within trench LA north of the Royal Road. These were sealed by two floors of LMIB and LMIA date. The deposit was made up of a sequence of fills (?) and interpolated floors/occupation surfaces, dating to EMIII (Floors III and IV), EMIIB (Floors V and VI) and EMIIA (Floor VII). A few of these preserved some features, mainly remains of walls, one hearth and a structure made up of a single course of stones set in a circle (Feature αμ) (details of the stratigraphy with location of various features can be seen in Figure 3:3). In one instance the excavator is able to assert that floor VI (EMIIB) to the west of wall απ was an *internal* space (levels LA 112, 114), probably in use simultaneously with an *external* area (Level 108) to the east of the same wall. An opening in the wall connected the two spaces – presumably a door, since a stone with a socket for a doorpost was found by the wall. Excavation labels suggested that complete pots were found in Levels LA 108 and 105B. Floor IV (EMIII) was 'marked by an area of white plaster' 1.20x1.60m. Although not suggested by the excavator, this could also have been an internal space; the absence of defining walls may simply be a result of limited exposure.

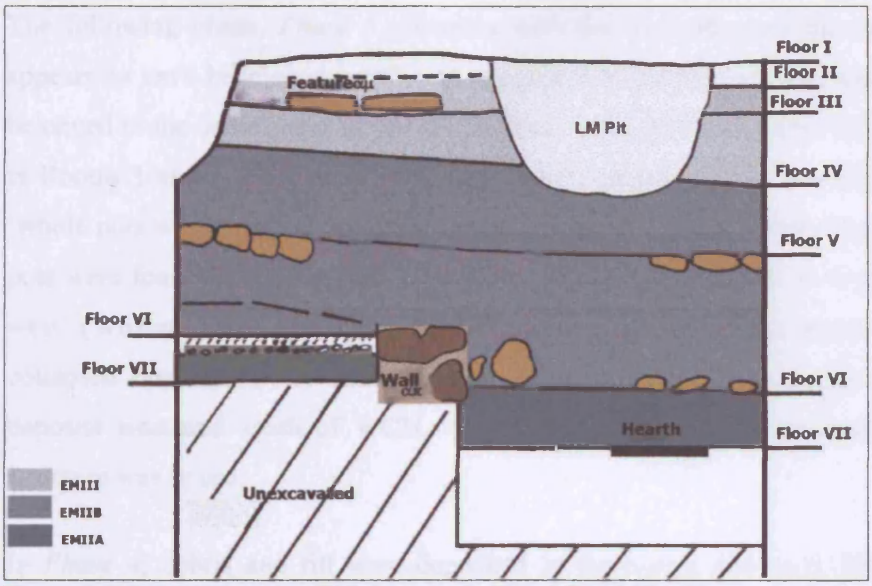


Figure 3:3 Section showing EM deposits in Royal Road North (courtesy of M.S.F. Hood, re-drawn for the purpose of the present study).

3.1.1.13.3 *EMIIA: West Court House*

J.D. Evans discovered WCH, a EMIIA structure concealed beneath the paving of the West Court, in the first year (1969) of his second campaign. Wilson subsequently studied the pottery and stratigraphy for his doctoral thesis in the early 1980s. The following brief description is based entirely on his findings[4], as these were published in a summary article (Wilson 1985) – J.D. Evans himself has not published an excavation report for WCH.

Wilson identified five phases in the construction, abandonment and levelling of the building which was eventually concealed by the laying-out of the paving of the West Court of the Palace. The earliest, *Phase 1*, preceding the construction of WCH, was dated to EMII and is represented by the cutting of a pit and a 'cutting' into Neolithic deposits under Rooms 1 and 2 and wall A. The infilling of these two features constitutes *Phase 2*. The fill, which was deposited very rapidly – 'there was no apparent evidence for any weathering or silting deposits' (Wilson 1985: 284) – consisted of loose earth, gravel and stones, while one fifth of the pottery was of Neolithic date. The rest of the pottery was contemporary with that of the floor deposits of the superimposed WCH and was dated to EMIIA. In this phase, the building of the structure also took place, of which three rooms were partially uncovered. These were most probably basement rooms, accessed, in so far as could be determined by excavation, through a single door located in the north wall of Room 3. Its floors were made up of trodden earth containing few sherds.

[4] Dr. Wilson kindly provided lists of excavation contexts and stratigraphic details for this study.

The following phase, *Phase 3,*coincides with the occupation of the structure. The building appears to have been used briefly, as suggested by pottery analysis and stratigraphy: pottery belonged to the same phase as the fill of Phase 2 (i.e. EMIIA), while only one floor was found in Rooms 1 and 2 and possibly two in Room 3. Of interest are two observations: firstly, that 'whole pots were lying smashed on the trodden earth' and, secondly, that 'joins from the same pots were found throughout the three rooms of the house as well as in the yard outside to the west' (Wilson 1985: 290). These led Wilson to suggest that the vessels originally stood on a collapsed upper floor, or roof terrace. Contemporary with these floor deposits were yard deposits west and south of WCH, which appear to have accumulated gradually, while the structure was in use.

In *Phase 4*, debris and fill were deposited in the rooms and yard. These contained plaster, charcoal, fragments of burnt mudbrick, and layers of collapsed and disintegrated mudbrick. According to Wilson there are two possibilities: either the fill was derived from a collapsed upper structure or it was brought from elsewhere (another building or other rooms of the same building) in order to infill these rooms. Infilling took place very soon after WCH went out of use, since the pottery in this phase also dates to EMIIA. Wilson suggested that the absence of evidence for fire or earthquake destruction implies a deliberate abandonment and infilling of the building, in the context of a program of spatial re-organisation of this area (Wilson 1985: 290). To the final phase, *Phase 5,* belonged mixed deposits containing EM-LM pottery. These constituted the packing underneath the West Court paving. Because of its potentially mixed character, faunal material from this final phase was not analysed.

3.1.1.13.4 *EMIIB-EMIII: Palace Early Minoan and Early Houses 1993*

PEM explored the north-western part of the Early Houses, an area excavated by Arthur Evans early in the 20th century. Only three small trenches were dug in 1961 revealing EM floors and fills. The area was re-excavated in 1993 by Momigliano and Wilson, as the Early Houses represent the first substantial EMIIB-III architectural remains found at the Palace, preserving the best stratigraphic sequence for this period (Momigliano and Wilson 1996: 1). The PEM excavations by Hood have not yet been published, but Momigliano and Wilson's report elucidates the history of the area and covers sufficiently findings by Hood, as well as Arthur Evans. Hence, the following summary is based on their discussion of their findings, which incorporated those of the two previous excavators.

The area of the Early Houses yielded a sequence of deposits from EMIIB to EMIII. Architectural remains survived only from the EMIII period, representing three building phases, the latest – dubbed South Front House by Mackenzie (Momigliano and Wilson 1996: 54) –

being by far the best preserved. The deposits unearthed were fills between floors, fills of wall foundation trenches, floors, and one EMIIB pit.

3.1.1.13.5 *MMIA: Royal Road South*

MMIA deposits were found in the RRS excavations by Hood. A MMIA floor was uncovered over basement floors (Hood 1960: 23), while a large MMIA rubbish deposit had filled a gulley in the western part of the excavated area before the construction of the first buildings (Hood 1960: 23; Momigliano 1991: 152).

3.1.1.14 *Old Palace deposits*

3.1.1.14.1 *MMIB: Early Houses 1993*

The second area explored by Momigliano and Wilson in 1993 was the 'Early Paving' adjacent to the Early Houses. More precisely, $2m^3$ of soil constituting fill below the paving were excavated, which contained eight zembils[5] of pottery dating to MMIB, in very fragmentary and worn condition.

3.1.1.14.2 *MMIB-MMIIA: Royal Road South*

Here a MMIIA pottery cache from the 'earlier destruction' of the Palace was discovered in 1957 (Hood 1958: 22) and excavation continued in 1958, yielding more complete vessels (in the northern part of this area was found the MMIA fill mentioned above). Three successive deposits were found, stratified above the floors of basement rooms; the earlier (MMIB) contained a large number of complete vases (Hood 1960: 22).

3.1.1.15 *New Palace deposits*

3.1.1.15.1 *MMIIIB: RRS*

A cache of complete vases of MMIIIB date was uncovered from the 'earlier destruction' of the Palace (Hood 1958: 22).

3.1.1.15.2 *RRN*

A large building, subsequently badly damaged, must have stood in this area in the Neopalatial period. Its walls were robbed entirely sometime after the destruction of the palace in LMII. The excavator in his brief report concentrates on an area which revealed large quantities of fragmentary pottery of LMIB date but also a number of ivory objects, which he interpreted as inlays of a wooden box. Because of these finds, the deposit was dubbed the 'Ivory Deposit'.

[5] Large rubber basket with approx. capacity of 32lt of soil.

Numerous chips and flakes of what was identified as ivory were also recovered, suggesting to the excavator that this may have been an ivory workshop (Hood 1960: 24). Through the floor of the 'workshop', a test trench was cut which revealed LMIA, MMIIIB and MMIA deposits (Hood 1961: 26-7).

3.1.1.15.3 *Road Trials (RT) west of the main Herakleio road*

In this area, excavated in the context of a rescue operation (widening of the road to Herakleio was planned), MMIA to LMIII deposits were found, but no other information is provided in the brief *AR* reference (Hood 1961: 27).

3.1.1.15.4 *Hogarth's Houses (HH)*

Excavations in this area began in 1956 and revealed a structure with three successive rebuilding phases (MMI to LMIII). A LMI house shrine, associated with cultic equipment (a poros stone altar and triton shell), and a concentration of votive conical cups resting on a patch of a pebble floor were discovered in 1957, much disturbed by modern ploughing (Hood 1958: 22).

In 1958, near House A originally excavated by Hogarth, a corridor leading to three adjoining rooms was found, built in LMIA and destroyed in the same period. Its rear wall was built of stones and stood to a height of 3.0m, but internal partition walls were built of mud or mudbrick. These were interpreted by Hood as storerooms and a kitchen: storage jars were found broken *in situ*, a stone mortar was sunk into the floor and there were traces of fires on the floors. The destruction of these rooms was sealed by a thick layer of ash and rubbish containing LMIB pottery. To the west of this complex a terrace was excavated, whose fill consisted of LMIA rubbish, bearing remains of flimsy structures interpreted as outbuildings and associated with Hogarth's House A. In the upper levels, evidence was found for habitation until LMIII (Hood 1959: 18-9).

3.1.1.16 *Final Palace deposits*

3.1.1.16.1 *RRS*

The only information available for deposits of this date is that they were first located in RRS in 1957, dated to LMIIIA1 and contained several ivory objects, namely, parts of statuettes and 'house façades'. In a sounding under the Royal Road itself, an LMII deposit showed that the now visible road dates to the FP period (Hood 1960: 23).

3.1.1.16.2 *RRN*

No description of the Final Palatial deposits from this area is available in Hood's preliminary reports.

3.1.1.17 *Summary*

Evidently, sophisticated contextual analyses of the faunal remains cannot be undertaken at this stage. Some periods are represented by few deposits, whose characterisation is uncertain (e.g., PW, WCH, EH93, RR Old Palace), while others have the potential of providing more detailed information, but fuller publication of their archaeological contexts is required. What is important to bear in mind, however, is that the vast majority of the BA deposits studied are included in the area characterised as public/elite core in Whitelaw's study of the organisation of the site in the Neopalatial period (Whitelaw 2001: 26, fig. 2.8) (Figure 3:1).

4 METHODS OF ANALYSIS

4.1 Introduction

The essence of archaeology is the investigation of past human behaviour through the analysis of its material remains. Not all types of behaviour produce such material remains, while only a sample of the original population is eventually deposited, and still less preserved to the present. Ultimately only a fraction of the above is recovered during excavation and part of it analysed. On the other hand, interpretations are very much dependent upon the methodology adopted by the researcher for the analysis and interpretation of material remains. The need to recognise explicitly the existence of such 'filters' and to formulate adequate theories and methods to ensure reliable archaeological inference was advocated and presented systematically by Clarke (Clarke 1973) and many other researchers subsequently (e.g., Schiffer 1995). Similar models, applicable to faunal studies have been presented by Maltby (1985) and Payne (1985a).

Since the aim of the present study is to use faunal remains to explore past human behaviour, the following section will outline a methodology for investigating the history of the faunal assemblages under study from deposition through to excavation and storage. The chapter begins with a brief summary of Clarke's model of the process of archaeological inference and its application to faunal analysis by various researchers. It continues by describing the types of data gathered in the field and the recording protocols employed, and concludes with the methods used in their analysis and interpretation, the latter drawing heavily on ethnographic and experimental observations of relevance to faunal analysis.

4.2 Methodological framework

4.2.1 Clarke's model

Clarke identified four 'steps latent in any archaeological interpretation' (Clarke 1973: 99-100):

(1) 'The range of hominid activity patterns and social and environmental processes which once existed over a specified time and area' (Clarke 1973: 99);
(2) Processes leading to material being 'deposited at the time' as a result of (1);
(3) Processes leading to the survival of a fraction of (2) until it is unearthed by archaeologists;

(4) Choices made by archaeologists leading to a fraction of (3) being recovered.

For the analysis of each, he advocated the need for suitable bodies of theory:

Pre-depositional and depositional theory linking 1 and 2. Pre-depositional theory covers all aspects of human behaviour and its material remains, if any, while depositional theory deals with all agents, human, animal and environmental, which may affect material remains from the moment of their deposition until burial.

Post-depositional theory linking 2 and 3. This should cover all types of modification, from the moment of burial to that of excavation, resulting from the activity of a number of agents, human, animal and environmental, which, through mechanical and chemical processes, alter the material originally deposited.

Retrieval, analytical and *interpretive* theories, which encompass all aspects of the involvement of archaeologists with material remains from recovery to publication. They include methodological choices, such as excavation and recovery techniques, sampling strategies adopted by excavators, and analytical methods adopted by post-excavation researchers, which not only lead to particular subsets of material being retained and stored, but also affect the data and interpretations put forward.

4.2.2 Methods for investigating the history of faunal assemblages

Since Clarke's 1973 paper, many researchers have addressed related theoretical and practical problems and proposed models and terminologies. Zooarchaeologists have been particularly active in this respect. Starting with the final stage in Clarke's scheme (Step 4), methods of excavation and analysis by the specialist – recovery, quantification, and identification methods – have been scrutinized to identify their effect on data collection and interpretation (e.g., for recovery methods, see Payne 1972, 1975b; for quantification methods, see O'Connor 2000: 54 ff. for an overview and further references). In a Greek context, where the skeletal remains of two of the commonest species, sheep and goats, are characterised by considerable morphological overlap, precision of taxonomic identification often varies between analysts. It may be affected by familiarity with the material, availability of reference specimens in the field, or may reflect insufficient preservation. It is thus common to avoid differentiation between the two species, compromising the value of data interpretation. For materials analysed by other specialists, such as the present Knossian assemblage,

treatment may have involved selection and discard following original analysis; storage damage and loss of contextual information through deterioration of packaging are also likely hazards. Methods of excavation are crucial for the usability of faunal material: only that derived from a stratigraphically controlled excavation is suitable for the type of detailed analysis advocated here.

Stages 2 and 3 have been explored using concepts and observations from *taphonomy* – 'the science of the laws of embedding or burial' (Lyman 1994: 1) – a field of enquiry which had been developing independently within the disciplines of archaeology and palaeontology until the 1970s (Lyman 1994: 17). A vast range of modifying, mechanical and chemical processes become active from the moment bones are embedded in a soil matrix. These processes are attributed to a variety of agents: the weight of overburden and superimposed structures, trampling, changes in temperature and humidity, the activity of soil micro-fauna and plants (etching caused by roots), and so on. Most common effects on bones are *encrustation, staining, erosion,* and *fragmentation.* These agents act in combination and their impact appears to be dependent upon the treatment bones had undergone before burial. As a result, identifying in detail the mechanisms of alteration has been very problematic, even in the most controlled of actualistic studies (e.g., Nicholson 1992; 1996).

After human processing and consumption of animal carcasses, but before burial, especially if burial occurs after a period of months or longer, several agents may induce changes similar to those inflicted by post-depositional ones. Thus, loss of structural integrity may be caused by *weathering* due to changes in temperature and humidity, *trampling* by animals and humans, *scavenger attrition,* or post-discard *burning.* Scavenger attrition of bone remains, in particular, has been subject to experimental (e.g., Payne and Munson 1985) and ethno-archaeological studies (e.g., Binford 1981; Brain 1981), which have shown that the degree to which scavengers can affect bones depends on their structural density (Lyman 1994: 234), which in turn depends on the part of the skeleton, and on the size, age and nutritional status of the animal; the larger and closer to adulthood the animal, the more robust and less prone to complete or partial destruction are its bones.

Step 1, the study of pre-depositional processes related to intentional human behaviour, is an area of research also extensively explored in relation to animals. It can be divided into two major fields. The first encompasses studies of the processing and consumption of animal *primary* products, i.e. those procured after the death of the animal. A model of potential carcass processing stages has been proposed by O'Connor (1993), while several ethnographic and experimental studies have explored the relationship between carcass processing and anatomical representation (e.g., Binford 1978) or butchery mark placement (e.g., Bez 1995; Binford 1978; 1981; Burke 2000), the

relationship between cut mark morphology and type of butchery tool used (e.g., Greenfield 1999; Walker 1978; Long and Walker 1977), and the use of carcass products as raw materials (e.g., MacGregor 1985; 1989). While these studies have concentrated on practical aspects of animal processing and consumption, others have dealt with the consumption of animals in a social and symbolic context (e.g., Ingold 1986; 1991; various papers in Ryan and Crabtree 1995). Secondly, historical and ethnographic studies have explored management strategies in a pre-mechanised environment (e.g., Halstead 1998b; McCormick 1992; Payne 1973a) and the potential for distinguishing different strategies on the basis of age and sex composition, metrical and pathological evidence (see section 4.3.9 for references).

Evidently, interpretation of the data yielded is rarely a straightforward undertaking. Step 4 studies require adequate records of the methods employed during excavation and analysis; steps 1-3 are complicated by problems of equifinality and the limitations of analogical reasoning. These have been noted, for example, in the context of depositional and post-depositional processes (e.g., Nicholson 1996) and of ethnographic and historical studies of animal management (e.g., Halstead 1998b; McCormick 1992). Nevertheless, animal bones, like all other bioarchaeological material and in contrast to artefacts (e.g., pottery, architecture), combine a set of constant characteristics, such as anatomical consistency (e.g., constant numbers of elements in the skeleton of a given species). Moreover, as Lyman notes, 'bias in a taphonomic sense is relative to the question being asked of the fossils' (Lyman 1994: 32, quoting Wilson 1988). The biases from non-human agents are *directional*, that is, modifications from the action of such agents will result in a limited range of *predictable* effects, and only the *degree* of modification will vary depending on the intensity of impact.

The following sections present, first, the methods of data collection in the field and, secondly, the methods of data analysis and interpretation.

4.3 Stage 1: Field methodology

4.3.1 Sampling strategy

Faunal material from various excavations at the site of Knossos was examined, covering the whole of the Neolithic and the Bronze Age to the end of the Palatial period (LMIIIB) (Table 4:1).

Although available, the faunal remains from the Unexplored Mansion and from Stratum I (J.D. Evans' 1957-60 campaign) were not included in the present study because precise contextual and dating information was temporarily unavailable. In addition, only about a half of the available material of LN date from J.D. Evans' second campaign was analysed due to time constraints.

Table 4:1 Excavation campaigns from which faunal material was analysed

Excavator	Date of excavation	Period	Area
J.D. Evans	1957-60	Aceramic-FN	Central Court
J.D. Evans	1969-70	Aceramic-EMIII	Central Court; West Court; Peripheral Soundings
M.S.F. Hood	1957-61	EM-LMIIIB	Royal Road; Palace Early Minoan; Hogarth's Houses; Road Trials
D. Wilson and N. Momigliano	1993	EM-MMIB	Early Houses

Due to the lack of final reports for all but the excavations by Wilson and Momigliano, the analysis focused more on exploring temporal than spatial patterns. The chronological divisions used were those listed in Table 4:2, which follow the traditional breakdown of cultural horizons defined by pottery types. The divisions are, for the Neolithic, those suggested by the excavator (J.D. Evans 1964) and, for the Bronze Age, those defined by broader social and cultural changes on Crete. Analysis of spatial context is largely restricted to comparison of different excavation areas, e.g., WC and CC for the Neolithic, although some more detailed analysis is possible for some BA contexts.

Table 4:2 Chronological table for the prehistoric period on Crete (after Broodbank 2000 for BA; after J.D. Evans 1964 for Neolithic).

Years BC (approx.)	Relative chronology	Events
	Late Minoan II-IIIA/B	Mycenaean Palaces
1200	Middle Minoan IIB-Late Minoan I	New Palaces
	Middle Minoan IB- IIA	Old Palaces
2000	Early Minoan III -Middle Minoan IA	
	Early Minoan IIA-IIB	International spirit
3000	Early Minoan I	
4000	Final Neolithic	Cave occupation; Metallurgy; Secondary Products
5000	Late Neolithic	Settlement expansion
	Middle/Late Neolithic Transition	
	Middle Neolithic	
	Early/Middle Neolithic Transition	
	Early Neolithic II	
	Early Neolithic I	
7000	Aceramic Neolithic	Earliest attested settlement

Bone groups were selected for detailed analysis on the basis of chronological integrity: material from deposits containing pottery dating to three or more of the above horizons was excluded. Within these groups, only selected anatomical parts were recorded individually in detail.

4.3.2 Criteria for the selection of recordable specimens

The selection of fragments for identification and recording follows the method used by Halstead (Halstead *in press* b), an adaptation of Watson's method of diagnostic anatomical zones (Watson 1979). Of the recovered faunal assemblage, Table 4:3 shows skeletal elements (whether complete or fragments thereof), which were selected for recording if identifiable taxonomically to species or to a group of closely similar species (sheep/goat, red deer/fallow deer, horse/donkey). The aim of the method is efficient capture of information on anatomical and taxonomic composition, age, sex and metrical properties and so focuses on body parts that are relatively robust, identifiable and informative.

Table 4:3 List of skeletal elements selected for analysis

Cranial	Post-cranial
Horncore/antler tips and bases	Scapula (articulation and 'neck')
Mandibles (d3/P3-M3; canine-M3 for pigs; loose d4, P4, M1-3 and pig canines)	Humerus
	Radius
	Ulna (proximal only)
	Metacarpals (only 3 and 4 for pigs)
	Pelvis (acetabulum and immediately adjacent parts of ilium, ischium and pubis)
	Femur
	Tibia
	Calcaneum
	Astragalus
	Metatarsals (only 3 and 4 for pigs)
	Phalanx 1-3 (excluding pig lateral phalanges)

The method excludes skeletal elements which:

- are subject to acute recovery bias due to their size and morphology (e.g., carpals and tarsals, other than calcaneum and astragalus);
- are difficult to identify to taxon (e.g., ribs);
- are not easily quantifiable because of high rates of fragmentation (e.g., crania and vertebrae).

4.3.3 Sorting of bone for detailed recording

Bones recovered during excavation had been stored by previous researchers in bags by excavation unit, bearing labels with contextual information (trench and level number). For each of these bags, the contents were strewn and specimens belonging to the parts selected for detailed recording were separated from those to be returned to the bag. At this stage, a careful search was made for any

mendable fresh breaks and those found were glued. In addition, a note was of made of any articulating specimens (e.g., matching distal humerus and proximal radius), of any matching unfused diaphyses and unfused epiphyses, of any plausible left-right pairs and of any other evidence for the deposition of whole or part-skeletons.

Specimens selected for detailed recording were then washed in tap water using toothbrushes and marked with the relevant contextual information, using indelible – water- and light-resistant – marker pens. Specimens were then sorted first by body part and then by taxon. It should be noted here that bone from the various contexts was grouped, sorted and quantified within the temporal units listed in Table 4:2, further sub-divided into spatial units when sufficient contextual information was available to make this possible.

4.3.4 Taxonomic identification

Identification of bone specimens to element and taxon was undertaken in the field using both published and unpublished criteria and prepared skeletal elements from various reference collections. Moreover, a great number of identifications – especially of sheep and goats – were verified by Dr. Halstead (both at Knossos and in England) and Dr. Martin (in England). The following table lists the various published and unpublished criteria used.

Table 4:4 List of sources used in taxonomic identification

All taxa	Halstead & Collins *unpublished manuscript*; Schmid 1972
Sheep vs. goat post-cranial elements (excluding phalanges)[1]	Boessneck 1969; Boessneck *et al.* 1964; Halstead *notes*; Kratochwil 1969; Payne 1969; Prummel and Frisch 1986; Rowley-Conwy 1998;
Sheep vs. goat mandibles and permanent mandibular teeth	Halstead *et al.* 2002
Sheep vs. goat deciduous teeth	Payne 1985b
Hare vs. rabbit	Callou 1997
Red vs. fallow deer	Lister 1996
Cattle horncore	Armitage 1976
Cattle vs. red deer	Prummel 1988b
Cattle front vs. hind phalanges	Dottrens 1946

For the study of the material stored at Knossos, the bulk of the modern reference specimens were loaned from the Environmental Unit of the Fitch Laboratory of the British School at Athens. Additional material was loaned from the Institute of Archaeology, UCL, and Dr. Halstead's own

[1] No attempt was made to speciate phalanges, as the criteria suggested by Boessneck *et al.* (1964) have been shown to be rather unreliable (Martin pers. comm.).

field collection. All limb bones selected for analysis from the following species were taken to the field:

- Cattle (*Bos taurus*)
- Donkey (*Equus asinus*)
- Sheep (*Ovis aries*)
- Goat (*Capra hircus*)
- Dog (*Canis familiaris*)
- Fox (*Vulpes vulpes*)

and complete skeletons of:

- Hare (*Lepus europaeus*)
- Badger (*Meles meles*)
- Marten (*Martes martes*)

All the above belonged to animals collected in Greece and the following to farmed animals acquired in England:

- Wild boar (*Sus scrofa*)
- Red deer (*Cervus elaphus*)
- Fallow deer (*Dama dama*)
- Roe deer (*Capreolus capreolus*)

The wild boar skeleton was considered more appropriate, as archaeological skeletal remains of pigs tend to resemble wild animals in build and morphology more than modern farmed individuals, which are also culled too young (when their bones are mostly unfused) to be very useful in an archaeological context. For identification of the material studied at the Institute of Archaeology, UCL, the Institute's faunal reference collections were used.

4.3.5 Quantification

Of the anatomical parts selected for study (above 4.3.2), any specimen identifiable to taxon (above, 4.3.2) and, in the case of long bones, to the proximal and/or distal half of the bone, was recorded as detailed below. Where two or more freshly broken fragments were joined or a matching unfused diaphysis and epiphysis were recognised, only one record was made; old breaks were not mended and were recorded as separate entries. The summing of these records for different anatomical parts, taxa and context groups would yield counts of numbers of identifiable specimens (NISP).

The proximal and distal parts of some long bones differ greatly in terms of age of maturation, resistance to attrition and nutritional value (Binford 1978). For this reason, the quantification method employed here is based on 'anatomical units' (Halstead *in press b*) and treats long bones as consisting of two halves or 'anatomical units', proximal and distal. Elements for which the proximal/distal division does not apply (i.e. horn/antler, mandible/mandibular teeth, scapula, ulna, pelvis, calcaneum, astragalus and phalanges 1-3) are recorded arbitrarily as proximal units. The summing of these records, with the proximal and distal halves of long bones treated as separate anatomical units, yields counts of *maximum* numbers of anatomical units (MaxAU).

Because different body parts are more or less likely to break into identifiable fragments and, in some cases (e.g., phalanges), occur in different numbers in different taxonomic groups, an attempt was also made to estimate *minimum* number of anatomical units (MinAU). Once fragments were sorted by body part, taxon and chronological/spatial group, a further search was made for real and potential joins (fresh or old breaks) or matches (paired body parts, articulating body parts). Where more than one fragment could conceivably belong to the same anatomical unit (taking account of side, size, robusticity, age and sex, when possible), even if they do not physically join, only one – usually that preserving most information on age and sex – is counted for MinAU. A similar procedure was used to control for variation between species in numbers of foot bones. Thus, for example, if two first phalanges of cattle or a third and fourth proximal metacarpal of pig could have been derived from the same foot of the same individual animal, only one specimen was counted for MinAU. The search for such potential joins and matches was conducted on chronological/spatial sub-assemblages determined on archaeological grounds (see section 4.3.1 and Table 4:2).

Of the two forms of quantification used in this study, MinAU is normally preferred for estimates of the relative abundance of different anatomical, taxonomic, age and sex groups, to minimise the over- or under-estimation of certain categories because of variation in survival, fragmentation,

identifiability and anatomical structure. Conversely, MaxAU is mostly used in estimates of the relative frequency of different forms of bone modification (gnawing, butchery, burning, fragmentation), because the procedures used to calculate MinAU may inadvertently lead to selective discounting of some of these categories (see below 4.4.4.1).

4.3.6 Recorded variables

For each specimen regarded as identifiable, the following information was recorded when appropriate/available:

- Body-part
- Taxon
- Presence/absence of proximal/distal zones
- Fusion state of proximal/distal zones
- Side of body
- Fragmentation
- Gnawing/burning/erosion
- Cut marks (location, possible activity, possible tool used)
- Sex
- Measurements
- Pathology
- Tooth eruption and wear
- Evidence of bone-/horn-working
- Any actual joins or matches between different contexts

4.3.7 Gnawing, burning, surface alterations and fragmentation

Ingestion and gnawing of bones were identified macroscopically, using morphological criteria observed under ethnographic and experimental conditions. Ingestion is identifiable by the characteristic signs of corrosion of bone surfaces (Lyman 1994: 211, fig. 6.24). Characteristic gnawing traces include punch marks, pitting and striations inflicted by the canines and cheek teeth

of carnivores or pigs and parallel grooves inflicted by the incisors of rodents (for carnivores see Lyman 1994: 208-11, figs 6.20-23; Binford 1981; Payne and Munson 1985; Munson 2000; for pigs see Greenfield 1988: 478 & fig. 1; for rodents see Lyman 1994: 196, fig. 6.15b; for sheep see O'Connor 2000: 50, fig. 5.8). There is overlap in the morphology of tooth marks inflicted by carnivores, pigs and even herbivores, but it is more important to identify the existence and impact of this type of attrition than to attribute individual examples to particular agents. Gnawing traces were thus differentiated only between rodent and 'other'.

Burning was recorded on a presence/absence basis. Specimens were identified as burnt if they exhibited brown/black/white/blue-grey discolouration from the surface inwards. A detailed assessment of the temperatures to which individual bones were subjected was not possible, as it has been shown experimentally that only microscopic examination can provide reliable estimates of temperatures (Shipman *et al.* 1984), and the necessary facilities were not available in the field. Discoloration, such as superficial brown patches, was not recorded as burning, as it could have resulted from chemical staining in the ground.

Weathering is difficult to record objectively. Nominal-level measures (Lyman 1994: 98) could have been used (e.g., good, medium, poor), based on visual assessment of surface condition. Analyst subjectivity is inherent in this type of 'measurement' and the potential rewards were not considered to justify the time and effort needed to record each specimen in this way. Consequently, surface condition of *groups of bone*, rather than individual specimens, was noted to identify cases of extremely poor surface preservation. It soon became evident that groups thus affected were very rare, probably a function of the soils (alkaline marls) and the character of the site: Knossos is essentially a tell formation on a low hill and many of the earlier deposits were buried under several metres of deposit due to the continuous occupation of the site over millennia.

Type of *fragmentation,* that is part of the bone preserved, was recorded for complete and partial specimens of long bones (i.e. humerus, radius, femur, tibia and metapodials), excluding freshly broken specimens where fresh breaks obscured old – pre-excavation – fragmentation. The scheme, devised by Halstead & Martin and based on Binford's ethnographic observations (Binford 1981: 171), differentiates between the following categories:

- Whole bone
- Whole bone with part of shaft missing

- Articular end
- Articular end with shaft
- Splinter of articular end and shaft
- Shaft cylinder
- Shaft splinter

Of these categories: cylinders are characteristic of scavenger attrition; broken specimens including all of part of the articular end are characteristic of human extraction of marrow; shaft splinters commonly result from human marrow extraction but also from intensive carnivore attrition; and whole bones are typical of assemblages free from anthropogenic, carnivore and other post-depositional breakage.

4.3.8 Identification, recording and interpretation of butchery marks

Butchery marks were observed macroscopically using a hand lens (x6 and x10 magnifications). For each specimen bearing marks, two variables were recorded. First, marks were differentiated as resulting from: a) cutting with a slicing tool, such as a metal knife or chipped stone implement; b) sawing, with an implement with a serrated edge; c) chopping, with a heavy cleaver/axe. The differentiation between the three types was based on the morphology of the butchered surface. Cut marks were thin grooves resulting from the slicing motion of a knife-like tool. Sawing left characteristic flat surfaces with sets of striations at varying angles, and occasionally shelves (e.g., MacGregor 1985: 56, figs. 32, 33). Chop marks consisted either of large flat surfaces, which differed from sawing in that macroscopically visible striations were absent, or, in cases where the bone had not been cut through, of indentations considerably deeper and wider than those resulting from cutting.

The identification of different types of tools, interesting from a technological point of view, was selectively extended in the case of cut marks to identifying stone vs. metal marks. Various studies have tried to produce criteria to differentiate between the two. There are various drawbacks in the application, in detail, of their conclusions. Studies such as those by Walker, Long, and Greenfield describe a number of criteria, which are visible only under high magnification (SEM) and therefore not applicable in field conditions. An additional drawback of Greenfield's methods in particular is

the fact that the modern steel knives used in his experiments may not be appropriate models for marks inflicted by *early* copper and bronze cutting tools. Moreover, the medium on which the experimental cuts are inflicted is wood (Greenfield 1999: 799-801). Finally, results are inconclusive as regards the identification, beyond doubt, of metal vs. stone tool marks, and there may be overlap in the morphology of marks inflicted by early metal tools and certain types of stone tools – at least when viewed macroscopically (Halstead pers. comm.). For example, the long obsidian blades common on Early Bronze Age sites in Greece may have produced long sharp cut marks macroscopically resembling metal ones. The identification of stone and metal tool marks remains, however, very important for certain periods, as it sheds light on a major technological shift, the beginnings of the use of metal in tool manufacture and the displacement from various activities of stone tools (Greenfield 1999: 798; Collins and Halstead 1999: 139).

With the above in mind and within the constraints posed by time and field conditions and the ambiguities of the available methods, an effort was made to differentiate between stone- and metal-inflicted butchery marks, based on a set of relatively unambiguous criteria which could be observed macroscopically. These are derived from Binford (1981: 102), Collins (1987) and, to a lesser degree, Long and Walker (1977), Walker (1978) and Greenfield (1999) and are summarised in Table 4:5.

Table 4:5 Summary list of criteria for separating between stone and metal cut marks

Stone	Metal
Short cuts	Long cuts
Clusters of parallel cuts	Single or few cuts
NA	Overlapping shelf (Binford 1981: 102)
Wide triangular cross-section with one sloping and one straight edge	Narrow triangular cross-section with two sloping edges

The second variable recorded was the exact anatomical *location* of marks, from which, mainly following Binford (1981: 87ff.) and Bez (1995), the activity that had produced them was inferred. Where cut marks matched in terms of location those observed actualistically by Binford or Bez, they were categorised during recording as skinning (removal of skin and horn), dismembering (sectioning into parts), and filleting (removal of flesh). In addition all cut marks were recorded on diagrams of the relevant anatomical elements, enabling some 'new' locations subsequently to be attributed to one of Binford's stages of carcass processing on the basis of the soft tissues overlying the cutting site.

Finally, the last type of human modification recorded was the transformation of skeletal elements into implements. No further details were recorded at this stage of the study, due to time constraints. A more detailed analysis of bone working will constitute a separate future study.

4.3.9 Ageing, sexing, measurements and pathologies

Two types of age data were recorded:

- For post-cranial elements, the state of fusion was recorded as fused, fusing (when line between epiphysis and diaphysis was still visible) and unfused. Two further categories were used, based on texture and size, to characterise skeletal elements belonging to foetal/neonatal and very young (but post-neonatal) individuals. In the analysis of epiphyseal fusion data, fusing and very young specimens are grouped with unfused, but foetal/neonatal material is excluded.
- For mandibles/mandibular teeth, dental eruption and wear patterns were recorded. Roots of loose deciduous teeth were examined to identify possible shed specimens but none were observed.

The methods used to identify and record the above, follow the sources listed in Table 4:6.

Table 4:6 Methods used for ageing post-cranial elements and mandibles/mandibular teeth

Taxon	Postcranial elements after	Mandibles/mandibular teeth after
Cattle	Prummel 1987a & b, 1988a, 1989; Silver 1969	Grant 1982; Grigson 1982; Halstead 1985
Pig	Prummel 1987a & b, 1988a, 1989; Silver 1969; Bull & Payne 1982	Grant 1982; Halstead 1992a; Bull & Payne 1982
Sheep and goat	Prummel 1987a & b, 1988a, 1989; Silver 1969;	Payne 1973a; Deniz & Payne 1982

Sexing was limited to pelves of cattle (after Grigson 1982), sheep and goat (after Boessneck 1969) and pig lower canines (after Schmid 1972).

Measurements were taken using digital calipers, following von den Driesch (1976). Only four types of measurements were taken at maximum of each specimen (see Table 4:7), due to time constraints; usually, only one measurement was preserved. Unfused epiphyses were measured as well as fused examples (following Zeder 1999: 19-20; *contra* von den Driesch 1976: 4) in order to detect possible differences in the management of male and female animals. In the case of sheep and goat phalanges,

no measurements were taken, because of the lack of reliable criteria for differentiating between front and back, medial and lateral, male and female, and sheep and goat.

Table 4:7 List of measurements taken (for definitions see von den Driesch 1976).

ELEMENT	Measurement 1	Measurement 2	Measurement 3	Measurement 4
Scapula	LG	BG	GLp	SLC
Humerus	Bp	Bd	GL	SD
Radius	Bp	Bd	GL	SD
Ulna	DPA	SDO	LO	-
Metacarpal	Bp	Bd	GL	SD
Pelvis	SH	LFO	LA	LS
Femur	Bp	Bd	GL	SD
Tibia	Bp	Bd	GL	SD
Calcaneum	-	-	GL	GB
Astragalus	GLl	GLm	-	Bd
Metatarsal	Bp	Bd	GL	SD

Pathological specimens were observed and the presence of pathological conditions was recorded. Emphasis was placed on the observation and interpretation of traumatic injuries (Baker & Brothwell 1980: 8-92) and diseases of the joints, as these latter are thought to provide indirect evidence for the use of animals for draught purposes (Bartosiewicz *et al.* 1997: 3-80; de Cupere *et al.* 2000).

4.4 Stage 2: data analysis and interpretation

The ultimate aim of this thesis is to examine past human behaviour at Knossos, as imprinted in the material record of the faunal assemblage from the site. This assemblage has subsequently been transformed by post-depositional and excavation/post-excavation processes, that are not of interest *per se* to this thesis, and also by depositional processes (such as scavenger attrition), that may be of intrinsic interest in so far as they shed light on the spatial organisation and context of past human behaviour. It is important not to infer past human behaviour from patterns in the faunal record that might be products of depositional, post-depositional, excavation or post-excavation processes. For this reason, analysis is undertaken, and this thesis is organised, in reverse chronological order, beginning in Chapter 5 with the impact of post-excavation and then excavation procedures, followed by post-depositional and then depositional processes. This first analytical chapter ends by considering the implications of contextual variation in depositional variables for the spatial organisation of past human behaviour. The following two chapters are devoted to the investigation of past human behaviour and, for similar reasons, are placed in reverse chronological order. Chapter 6 examines human processing of animal carcasses ('deadstock'), at each stage excluding categories of data considered inappropriate (on the basis of Chapter 5) for the analysis in question. Chapter 7

examines human management of live animals ('livestock'), taking into account not only the results of Chapter 5, but also the ways in which the evidence for livestock management may have been transformed by human processing of deadstock.

4.4.1 Data processing

Faunal data recorded as described above were processed using SPSS routines[2], and results are presented in the relevant chapters in tables and figures as appropriate. In comparing results from different subsets of data (taxa, chronological groups, etc.), chi-squared tests are performed to evaluate whether similarities and differences between groups of data were statistically significant. Throughout this thesis, the terms 'statistically significant' and 'statistically highly significant' are used to refer to chi-squared values of $p<.05$ (and $\geq.01$) and $p<.01$, respectively.

4.4.2 Step 4: Exploring excavation and post-excavation biases

4.4.2.1 *The impact of previous analysts and storage on the assemblage*

In order to evaluate the impact of storage and handling by previous analysts on the assemblage, various types of evidence were used. Written and oral accounts of the post-excavation history of the assemblage were added to by 'archaeological' observations in the field of surviving packaging and labelling, as well as by analysis of data on fragmentation. As regards fragmentation, sub-assemblages with contrasting histories of storage and analysis were compared in terms of the frequency of fresh breaks (as a measure of damage suffered in excavation, transport and storage) and the frequency of long bone shaft splinters compared to other types of old breaks (as evidence for selective recording of specimens, and perhaps selective discard, by previous analysts). On this basis, the effects of previous analysts and storage history on the composition of various sub-assemblages were identified and their implications for further analysis were assessed.

4.4.2.2 *Evaluation of recovery*

Given the observations on the effect of recovery methods on the composition of faunal assemblages (Payne 1972; 1985a; review by Maltby 1985: 36-40), it was considered necessary to investigate systematically their impact on the assemblage under study, especially since the bone groups analysed were recovered using a variety of methods – both hand-recovery in the trench and sieving.

[2] The routines were originally designed by Glynis Jones and Paul Halstead and were modified according to the needs of the present analysis.

The evaluation of recovery relies, again, on three complementary lines of evidence: written and oral accounts of recovery methods practised; any clues to the same in surviving labels; and comparative analysis of the anatomical and taxonomic composition (as proxy measures of bone size) of different sub-assemblages. Analysis of the third line of evidence follows Payne in comparing 'the frequency of smaller and larger bones that lie close together in the skeleton' (Payne 1985a: 220). For the MDT (cow, pig, sheep/goat), MinAUs of *recovered* astragali and calcanea are tabulated and compared to *recovered* distal tibia MinAUs, and MinAUs of *recovered* phalanges 1-3 are tabulated and compared with *recovered* MinAUs of distal metapodials. The counts of distal tibiae and distal metapodials *recovered* are taken to reflect the minimum number of anatomically *expected* astragali and calcanea (on a ratio of 1:1:1) and phalanges 1-3 (on a ratio of 1:1:1:1), respectively. Counts of *recovered* astragali, calcanea and phalanges are then re-calculated as percentages of the Anatomically Expected Counts (AEC) to provide a measure of the efficiency of recovery; Maltby's (1985) method of calculating percentages was preferred to Payne's ratios, as it is easier to interpret.

In a poorly recovered assemblage, losses are expected to be most pronounced for the smallest third and second phalanges, gradually decreasing for first phalanges, astragali and calcanea in that order. Finally, losses due to recovery of these elements are expected to be most acute for the smaller-bodied sheep/goats, decreasing for pigs and almost non-existent for cattle. This analysis, as well as showing the effects of different methods of recovery, should provide a firmer basis for controlling for such biases in subsequent steps, such as calculation of relative frequencies of body parts, taxa and age groups in different phases and areas.

4.4.3 Step 3: pre-excavation post-depositional filters

The combination of problems of equifinality and of limitations imposed by the 'low-tech' methods of field observation common in zooarchaeological analysis means that the different taphonomic effects listed in section 4.2.2 can be studied at varying levels of detail and interpreted with varying accuracy as regards causality. This need not present a problem, since, depending on the purpose of the study, simple observation of presence/absence of at least some effects is sufficient. Thus, when it was observed during preliminary sorting and washing that the effects of *encrustation* and *staining* on the Knossos assemblage were negligible, these were not recorded for individual specimens. *Erosion,* on the other hand, appeared to have affected some bone groups on a larger scale. Since its cause could not be established, the evidence for erosion was used only to assess the degree to which it obscured gnawing and butchery marks. *Fragmentation* is the only variable that could be analysed objectively. The analytical methods employed are explained in detail in different sections below,

since, due to equifinality, agents of fragmentation can be pre- depositional, depositional and post-depositional and include intentional human processing, trampling and scavenger attrition.

4.4.4 Step 2: Depositional processes

4.4.4.1 *Scavenger attrition: methods and interpretation*

Scavenger attrition was explored for each of the various sub-groups in terms of its *frequency* and *severity*; presence/absence of gnawing and ingestion recorded for each specimen allowed the estimation of its *frequency* in the assemblage. In order to estimate frequency of attrition, MaxAU counts were used. They were chosen instead of MinAUs, since gnawed specimens are likely to be less informative of age, sex and even species than those not affected and so would tend to be discounted in MinAU counts, leading to underestimation of gnawing. In assessing the frequency of gnawing, the following were also excluded: specimens displaying heavy erosion, which will have masked any evidence for gnawing/ingestion; and loose teeth, which are unlikely to carry traces of gnawing.

Severity was assessed using two types of data. First, anatomical representation in Knossos sheep/goats was compared with Brain's modern observations on the effects of dog scavenging on the survival of various skeletal parts of goats in a South African village (Brain 1981). Secondly, analysis of fragmentation patterns in all MDT focused on Binford's observation that long bone 'cylinders', i.e. bones with their articular ends removed, are typical of chewing by scavengers (Binford 1981: 51); the frequency of cylinders to old breaks preserving all or part of the articulation served as one index of the contribution of scavenger attrition to bone fragmentation.

Brain's anatomical analysis was adjusted to take account of differences in methods of quantification[3]. In this study, MinAUs of each anatomical area for the combined sheep and goat remains were calculated and ranked in the order proposed by Brain (from the best-preserved to the least well preserved body part). Of the phalanges only the first were included, since recovery methods were likely to have severely compromised recovery of the smaller second and third phalanges. As in Brain's original study, representation of body parts was standardised to reflect their relative frequency in the skeleton – for example, first phalanges were halved to account for thir derivation from both front and back feet. While Brain treated proximal radius and ulna as a single anatomical unit, here the higher of the two counts was used, which in all cases was proximal radius.

[3] Brain uses NISP counts and specimens preserving their ends, while here MinAU counts are used of all specimens, including shaft and end/shaft fragments.

In the bar charts produced, following Brain's format, astragalus, calcaneum and first phalanx counts are highlighted as their numbers are likely to reflect primarily low recovery, rather than attrition. This method of assessing the severity of attrition was limited to sheep/goat remains only, as no equivalent modern study exists for cattle and pigs, while differences in size and structure make comparison of the latter with Brain's data for goats rather pointless.

The effects of scavenger attrition on bone assemblages – selective destruction of certain taxa, age groups and skeletal parts – are predictable. Recognition of the frequency and severity of scavenger attrition, therefore, may help the analyst avoid errors of interpretation in two ways: by highlighting patterns in the faunal data that should be attributed to attrition by other animals rather than to human behaviour; and by identifying particular sets of data that should be excluded from certain analyses. For example, an abundance of robust body parts in a heavily gnawed assemblage should not in the first instance be attributed to human selection, while specimens with gnawed articulations should perhaps be excluded from analyses of the frequency of butchery marks inflicted during dismembering.

As well as biasing assemblage composition and masking some types of evidence, scavenger attrition can be useful in providing clues to the conditions under which bone deposits were formed. Absence or very low incidence of gnawing on bone is plausible evidence for rapid burial or for deposition in bounded spaces to which scavengers had no access and *vice versa.* Analysis of evidence for gnawing may thus provide insights into human discard behaviour and organisation of space. Admixture of heavily gnawed specimens with others devoid of such marks is likely evidence for mixing of groups of different origin and implies that at least some of the material is a secondary deposition. The distinction between *pure/primary* and *mixed/secondary* deposits is also important in that the former is more likely to result from a single event or a single type of activity and so to preserve fine-grained information on past human behaviour, while the latter is likely to reflect a variety of disparate activities or post-depositional disturbance.

4.4.4.2 *Burning*

The presence of completely charred to calcined bone suggests exposure to high temperatures (Shipman *et al.* 1984), considerably higher than those produced during cooking. It is thus logical to assume that bone in such condition was burnt after discard or in a, presumably rare, cooking accident. In the context of deposition processes, the presence of burnt specimens was used to infer

mixing, when they occurred with non-burnt material, which is often the case. Other uses of the evidence for burning are discussed below.

4.4.5 Step 1: pre-depositional processes

The final stage of the analysis concentrated on exploring human behaviour in terms of *consumption* and animal *management* practices. The different methods employed are detailed in the sections below. Analysis of data as regards the practicalities of consumption drew mainly on the studies of Binford (Binford 1978; 1981). The application of utility indices was not attempted, due to the particular post-excavation history of the assemblage and the recovery methods employed during excavation.

4.4.5.1 *Processing for food consumption*

Butchery and burning: Butchery marks are used to explore a variety of processes. Different taxa and periods were compared to identify differences in the frequency of all butchery marks and thus in the intensity of carcass processing. The anatomical locations of butchery marks were used to identify successive stages of carcass processing and also to explore sizes of meat parcels and thus scales of consumption or, combined with information on the sizes of available cooking vessels, methods of cooking. Very localised burning was looked for, to infer roasting, on the premise that, on an open fire, bone unprotected by tissue may become slightly charred during cooking. Marks from different types of tools were juxtaposed with finds of stone, bone and metal tools to explore the adoption and use of new technology.

Human fragmentation of bone for within-bone nutrients: Deliberate human modification of bone for consumption purposes was differentiated from depositional and post-depositional fragmentation in three ways: by comparing the incidence of old breaks with the frequency of gnawing; by comparing the frequencies of old breaks on long bones in the form of articular ends and end splinters (characteristic of human extraction of marrow) with those in the form of cylinders (suggestive of scavenger attrition); and by comparing the incidence of fragmentation between taxa and age groups (large and robust bones of big and mature animals may be targetted in human extraction of marrow, while the bones of smaller taxa and younger age groups are more vulnerable to depositional and post-depositional breakage). Fragmentation patterns are not used to infer whether bone was broken when fresh or cooked, since results from experimental work show that different skeletal elements appear to respond differently depending on age (Alhaique 1997).

4.4.5.2 *Understanding depositional contexts*

The role of analysis of depositional and post-depositional processes in clarifying the nature of archaeological contexts (e.g., primary vs. secondary depositions) was discussed above (4.4.4.1). This can be taken further by considering evidence for carcass processing, in an effort to shed light not only on patterns of deposition, but also on the scale and location of carcass processing.

Evidence for the status of deposits (in addition to admixture of gnawed and un-gnawed, burnt and unburnt specimens) included the presence in a deposit of sets of skeletal elements which occur in proximity within a skeleton. These may be: matching bones (e.g., pig metacarpals 3 & 4 belonging to the same foot), matching unfused epiphyses and diaphyses (e.g., a proximal femur unfused diaphysis and its matching caput femoris), articulating elements (e.g., a distal humerus and proximal radius from the same leg). Such groups may have retained their proximity due to the presence of connecting tissues (e.g., meat, cartilage, sinews, skin) at the time of the original deposition. The organic composition of such tissues means that they would not have survived for a long time (months at best), and as a result would have linked the separate elements for only a brief period of time; after this, if these groups were moved, their structural integrity would have been lost. This is evidence that the deposits in which such groups occur were more or less undisturbed subsequent to initial deposition. As noted above (4.4.4.1) such groups are valuable, in that they are likely to be closer, in form and content, to the material originally deposited by humans and therefore more informative of human behaviour.

Relative frequencies of anatomical parts and of butchery marks from successive stages of carcass processing were investigated to identify whether parts of the operational chain took place outside the areas under study. Moreover, a concentration in any one context of parts of the skeleton (e.g., foot bones), which would derive from a particular stage of carcass processing might help to locate this in space. Contextual analysis of bone assemblages is most productive when analysis compares faunal material from different types of deposits (e.g., fills, floor deposits, pits, external/internal areas) and incorporates information provided by other bodies of material (e.g., pottery). Unfortunately, this type of information was not available at the time of analysis for the majority of the bone groups studied here. Thus the above could only be investigated in most cases from evidence provided by the faunal remains.

4.4.5.3 *Animal management*

The final stage of analysis of data concentrated on management of MDT, since other taxa/species were too rare to provide an adequate body of data for this kind of analysis. The following bodies of data were used. *Metrical data* for a range of body parts were employed to evaluate the possible existence of distinct populations, namely feral and domestic, by comparing ranges at Knossos from different chronological horizons with contemporary evidence from other Greek sites – the choice of comparanda mostly dictated by availability of published data rather than other considerations. Size ranges of different sub-phases were also compared to explore change or stability in body-size, which might be linked to management strategies favouring larger or smaller size.

The different types of age data, post-cranial fusion and tooth eruption and wear, were first compared to establish whether biases, such as differential retrieval, attrition or discard, may have skewed the results from either body of data. Subsequently, to address issues of management, only dental data were used, which are relatively free of scavenger attrition biases, especially for the smaller taxa, as well as offering better resolution of age stages and, in the case of sheep and goats, closer taxonomic identification. The interpretation of age curves follows Payne (1973a), rather than McCormick's (1992) critique, for reasons discussed by Halstead (1998), although in practice the nature of the mortality data from Knossos makes this debate of limited relevance to this thesis. Additional evidence for management was provided by sex ratios derived from morphological criteria and from the distribution of measurements. Stress-related pathologies for the larger cattle were also used to infer secondary use of animals.

4.5 Conclusion

Using the above methods of data analysis and interpretation, the following chapters will discuss first the taphonomic history of the assemblage, secondly the evidence for consumption, and finally the evidence for animal management. The concluding chapter will summarise the above trying to place conclusions in a wider archaeological context.

5 THE TAPHONOMIC HISTORY OF THE KNOSSIAN ANIMAL BONE GROUPS

5.1 Introduction

An essential prelude to analysis of the Knossos faunal assemblage in terms of prehistoric human behaviour is recognition of the ways in which the material has been altered since discard, by taphonomic, excavation and post-excavation processes. For reasons addressed in Chapter 4, these processes are here explored in reverse chronological order, beginning with modification during post-excavation work and then during excavation, before proceeding to analysis of post-depositional filters and, lastly, to analysis of spatial variation in post-depositional modification. While post-excavation and excavation modification are not of intrinsic interest, post-depositional modification may shed light on human behaviour, particular in terms its spatial organisation.

5.2 Post-excavation filters

Depending on the date when each excavation campaign was conducted, the various assemblages studied here have had different storage and analysis histories (e.g. some were studied by other zooarchaeologists). Storage facilities can play a decisive role in the preservation of contextual information and condition of faunal material. Poor storage may lead to deterioration of packaging and labels and thus to mixing and loss of contextual information, while inadequate packaging may exacerbate compaction and breakage. If severe, these processes may render part of the recovered assemblage unsuitable for analysis. The intervention of the specialist can equally transform the composition of an assemblage, if decisions have to be taken to keep or discard material. Such decisions depend primarily on analytical methods, but are also often dictated by storage restrictions, need for transport to a laboratory for analysis, etc..

The Knossos assemblages studied here have had a complex history of storage and earlier analyses, with most of the material being relocated several times and studied previously by other zooarchaeologists (M. and H. Jarman, O. Bedwin). The impact of storage and previous analysis, therefore, on composition of the extant assemblages, is explored in the following sections.

5.2.1 Storage

The material studied derives from four excavation campaigns. These differ both in terms of the time elapsed between excavation and faunal analysis (present and past) and in terms of storage history. These two parameters are closely interconnected. Starting with the least complicated case, the most recently excavated material is that from Momigliano and Wilson's 'Early Houses '93' (EH93) campaign in 1993. Because of its small size (ca. 222 NISP), the excavators reasonably decided not to have the faunal assemblage studied by a specialist for the excavation report, but to reserve it for analysis alongside other assemblages of the same date (Momigliano and Wilson 1996: 10). Moreover, at the time of EH93, the use of the sturdier plastic crates for storage, rather than the earlier cardboard boxes, was ubiquitous, while a purpose-built storage complex was available for excavated material at the BSA premises at Knossos, known as the Stratigraphical Museum (henceforth SM). Therein the EH93 material was stored from the time of excavation until it was studied for this thesis.

Given this storage history, only limited post-excavation damage would be expected. Indeed, hardly any mendable fresh breaks were found within individual bags, while fragmentation analysis shows that the proportion of identified specimens with fresh breaks, as opposed to old breaks and complete bones, is relatively modest at ca. 14% (Table 5:1). Additionally, the assemblage had not previously been studied, nor had its composition been altered, by another specialist.

To varying degrees, the situation is more complicated for the remaining three groups of material – Hood (1957-60), Evans1 (1957-60), and Evans2 (1969-70). All these groups were initially stored at Knossos, though not in the SM, which was built sometime in the 1970s – about 15 years after the first two excavation campaigns. Evans2 and Hood remained there, being moved around as new storerooms became available (C. MacDonald pers. comm.), to be finally deposited in the 'Fortetza Apotheke' where they are currently stored; Evans1 was transferred for study to the University of Cambridge in the late 1960s or early 1970s. The present author found material from all three campaigns stored by context in plastic (Evans2), paper (Hood) and cloth bags (all three), contained in cardboard boxes (ca. 0.60x0.40x0.30m – Evans2), in large wooden trunks (ca. 1.20x0.70x0.60m – Hood) and wooden boxes (ca. 0.60x0.35x0.40m – Evans1). The packaging of the Evans2 material had been partly replaced in the 1980s by Winder (see below), who probably used plastic bags. While Hood and Evans1 had remained in storage for slightly more than a decade before being studied by the Jarmans, Evans2 was studied on site, presumably during the excavation and shortly afterwards.

To what extent has the complex and varied recent history of the three assemblages affected their composition? Because of the lack of relevant documentation, answers must be sought by study of the material itself.

Storage and packaging provisions have had their toll on the condition of the material. Packaging largely withstood the ravages of time, rodents and insects, with cloth-bags proving more robust than those of plastic or paper. Rescuing Hood's material was a laborious undertaking, as paper bags had begun to disintegrate and thus had to be carefully repackaged to prevent mixing. Nevertheless, the proportion of bags destroyed, to the point that material became mixed, was negligible.

More serious deterioration, however, seems to have been caused by post-excavation breakage, presumably due to compaction and relocation. Bags contained both unidentifiable 'bone dust' and numerous freshly broken pieces of bone often from recognisable elements, which were too small to have plausibly been collected during excavation; such specimens from individual bags often exhibited mendable and non-mendable fresh breaks. Mandibles especially had often disintegrated into several unmendable bone fragments and loose fragmentary teeth could only be attributed to the same jaws by careful matching of the anterior and posterior wear facets of adjacent teeth.

To minimise damage caused by storage, the material from each bag was strewn to identify and mend as many fresh joins as possible. This was very time consuming but enabled most fresh breaks to be repaired and maximum information to be gleaned. The damage was least repairable in the case of Evans1. Material from this campaign (which was transported to England) shows a considerably higher proportion of freshly broken specimens than the other three assemblages (Table 5:1).

Table 5:1 Frequencies of complete bones, old breaks and fresh breaks by excavation campaign (MaxAU; MDT and long bones only; excluding foetal/neonatal specimens and loose epiphyses).

Types of fragmentation	EH93	Hood	Evans1			Evans2		
	All areas	All areas	All areas	Central Court only		All areas	Central Court only	
	All periods	All periods	All periods	Early	Late	All periods	Early	Late
Complete	9	416	246	139	91	380	45	81
%	6%	9%	4%	8%	2%	5%	4%	7%
Old Break	125	3736	4039	1164	2873	5835	986	923
%	80%	79%	68%	63%	70%	83%	81%	78%
Fresh	23	566	1670	532	1134	850	185	175
%	**14%**	**12%**	**28%**	29%	28%	**12%**	15%	15%
Total	157	4718	5955	1835	4098	7065	1216	1179

This does not appear to be an artefact of the particular deposits excavated by Evans1: Table 5:1 also presents both Evans1 and Evans2 Neolithic material from the CC only, broken down into 'Early' (EN-MN) and 'Late' (LN) sub-groups (the rationale for this chronological division will become

apparent below in section 5.2.2.1.3). The level of fresh breaks is almost identical between the two chronological sub-groups within each campaign, but differs strongly between campaigns.

Nor can the high level of fresh breaks be attributed to damage inflicted during excavation. The Evans1 and Hood campaigns were conducted more or less simultaneously and used the same or at least similarly trained local personnel for digging. It is reasonable to assume that similar excavation and recovery standards were applied and it is not likely that one set of workers was so much more careful and meticulous than the other.

Likewise, contrasting levels of fresh breaks cannot be explained by storage conditions at Knossos. Hood, although stored at Knossos for a decade preceding study by the Jarmans, has similar proportions of fresh breaks to Evans2 (analysed immediately) and the Momigliano and Wilson assemblage (which benefited from better storage). The only variable which distinguishes Evans1 from the remaining three assemblages is the export of the former to Cambridge. Unfortunately, the size and type of the containers in which the material was transported to England is unknown, while the current ones appear to have been built subsequently. The extent to which transportation damage to Evans1 has affected the composition of the assemblage becomes clearer in the following section, which considers the impact of previous analysts on the Evans1, Evans2 and Hood material.

5.2.2 Previous analyses of the faunal assemblages

All animal bone from Evans1, Evans2 and Hood was first analysed by M. and H. Jarman and helpers. Subsequently, part of the material was studied by Winder, whose research centred on the re-analysis of the data collected by the Jarmans, which had never been published in full. The following sections evaluate the scope, methods and outcomes of these earlier studies in order to establish whether previous studies have affected the composition of the extant assemblages and, in the light of this, whether re-examination of the material is likely to be fruitful. This discussion draws on the limited information published by the Jarmans concerning their methodology (Jarman and Jarman 1968), but is mostly based on observations collected by the present study, combined with information presented by Winder (1986).

5.2.2.1 *The Jarmans' analysis*

5.2.2.1.1 *The Jarmans' methodology*

Crucial for understanding the Jarmans' methodology is the statement by Winder that, in the 'Jarman recording routine', information was coded numerically for each individual specimen, which then constituted a unique record with a unique accession number in the database. Inspection of the stored material showed that individual bone specimens were marked with a unique number. After study by the Jarmans, it seems that the material was kept in the original excavation bags, or at least units, because marked specimens were usually mixed with unmarked ones, in a single bag containing original excavation labels. Thus it is possible to examine what part of the assemblage was considered identifiable by the Jarmans.

1. Identification

Information from Jarman and Jarman (1968), from personal observation of the marked material and from tables produced by Winder indicates which parts of the skeleton were considered recordable by the Jarmans: horncores; all loose teeth (mandibular and maxillary), maxillae and mandibles; atlas and axis; all long bones, scapula and pelvis; patellae, carpals and tarsals (including calcaneum and astragalus) and phalanges.

Compared to the present study, the Jarmans examined a slightly wider range of body parts, including some parts of the skeleton rejected by the present study, because they offer little information or are prone to high levels of loss during excavation (e.g., maxillary teeth, fibula, carpals, tarsals other than calcaneum and astragalus). Moreover, from examination of the marked and unmarked material, it was evident that the Jarmans' criteria of identifiability more or less matched those used here (as detailed in Chapter 4). Seldom were specimens found among the unmarked – therefore previously un-recorded – material, which were considered recordable by this study (and these may simply have been missed during the original sorting). Thus far the Jarmans' methods are entirely compatible with the present study.

On the other hand, taxonomic identification of sheep/goat specimens by the Jarmans is today of limited usefulness. Boessneck's most detailed study of sheep/goat speciation (Boessneck *et al.* 1964) was published only four years before the first Jarmans' article appeared, leaving the latter little time to familiarise themselves with the subtle morphological differences between the two species. Indeed, in this first publication of results from their Knossos study, they state that they consulted Boessneck, Hildebrand and Perkins (Jarman and Jarman 1968: 243) but that, because of

preservation, they used only a subset of their criteria to differentiate between sheep and goats. In their discussion of Aceramic and EN bone groups, 'only astragali and distal ends of metacarpals permitted a satisfactory estimation' of the relative abundance of the two species (Jarman and Jarman 1968: 243). The speciation of a wider range of body parts for Evans2 – metapodials, horncores, astragali, calcanea, distal humeri and distal tibiae (Winder 1986: 91, table 6) – indicates that they gradually became more confident in their application of published criteria. Nowadays, researchers have become more proficient in applying Boessneck's criteria. Moreover, additional criteria include, most importantly, ones for separating juvenile (Payne 1985b) and adult mandibles (Halstead *et al.* 2002), thus combining taxonomic and age information for two of the most commonly represented species in this assemblage.

In addition, sexing does not seem to have been attempted, while dental age was rather crudely recorded using Ewbank *et al.* (1964) (Jarman and Jarman 1968: 245; Winder 1986: 78-9), as neither Payne's (1973a) nor Grant's (1972) scheme was available at the time. Metrical data were recorded without access to the now standard handbook (von den Driesch 1976). Nor was information recorded on fragmentation, butchery, or surface condition (e.g., burning and gnawing marks), variables essential to consideration of taphonomy (cf. Winder 1986: 76). In this respect, it is revealing that the majority of the material was found unwashed – or, at best, only poorly so – which would have made reliable recording of gnawing and butchery marks impossible.

2. Quantification

The Jarmans themselves do not specify what their quantification method was in their 1968 publication but Winder reports that they recorded all specimens using a 'zone system' of proximal and distal parts, producing counts comparable with the MaxAU of the present study (Winder 1986: 80).

Acute problems are posed, however, by the Jarmans' application of this method of quantification. While re-strewing their material, it became obvious that minimum effort had been expended on joining freshly broken specimens. In one instance, eight fragments were found to belong to a single mandible. In the vast majority of cases, each of these joining fragments bore a unique accession number. Given that fragments glued together by the Jarman team were each given the same accession number, those with different accession numbers surely represent individual records in the Jarman database. This implies that many mendable specimens had been subject to multiple recording. The distribution of unique accession numbers indicates that this problem is particularly acute in the case of elements which, for structural reasons, exhibit high levels of both fragmentation

and identifiability, namely teeth and mandibles. The Jarmans themselves acknowledge this problem in the case of pig teeth, suggesting that fragmentation and identifiability will artificially have exaggerated the estimated representation of pigs in the Evans1 Aceramic to ENIb assemblages (Jarman and Jarman 1968: 24). Although cranial fragments were omitted from counts in their 1968 article (Jarman and Jarman 1968: 241), all tooth specimens – any upper, or lower jaw teeth, even those fragments not identifiable as one or the other – were included (Winder 1986: 105, table 14). The numbers of recorded specimens in Winder's tables derived from the Jarmans' database do not suggest any measures to reduce such 'noise'. In the absence of a methodology dealing with differential fragmentation, even in the case of fresh breaks, the Jarman data are of questionable value where rigorous quantification is paramount (e.g., in taxonomic and elemental representation).

3. Contextual information

The Jarman data no longer preserve contextual information, as the final computer generated results were grouped by period and a full catalogue of concordances between accession numbers and the contexts to which each recorded specimen belongs is not available (Winder 1986: 77). The implications of this are obvious and detailed discussion is not needed.

5.2.2.1.2 *The present usefulness of the Jarman data*

The above discussion is not meant as a criticism of the Jarman analysis. The methods applied were informed by the research questions addressed by the Early Agriculture Research Programme, of which the Knossos study was a part, but also limited by the analytical tools available at the time. Methods of taxonomic identification, quantification, ageing and sexing, and taphonomic analysis have advanced greatly since the Jarmans' study of the Knossos faunal assemblages. Moreover, as Winder notes (1994: 33), the project was too ambitious for the processing capacity of computers available at the time. Some loss of information between the original recording and the production of meta-files, where data were re-sorted and analysed (Winder 1986: 66, 76) may have been a conscious choice in order to deal with this shortcoming. The fact remains, however, that the Jarman data are now obsolete and unreliable and this must apply equally to the data from Hood's excavations, material from which was studied at the same time as the Neolithic assemblage[1].

[1] The Jarmans never published anything on this material, nor is there a study analogous to that of Winder's for the Evans material to draw upon.

Because the Jarmans preserved the contextual integrity of the assemblages, it was decided to re-study the material, taking advantage of additional dating and occasionally contextual information provided by the excavators, as well as analytic methods not available to the Jarmans. To this end, the impact of the Jarmans' study on the composition of the assemblages must now be considered.

5.2.2.1.3 *The impact of the Jarmans' study on assemblage composition*

In re-studying the Jarmans' material, it was noted that in a number of bags all specimens were marked, suggesting that those considered non-recordable had been discarded. This is largely the case with the Aceramic to MN material collected during Evans1 and Evans2, but is not apparent in later material from Evans1, Evans2 or Hood. In the case of Evans2, if material has been discarded, it should not significantly affect the present results, as criteria for selection of 'identifiable' specimens seem to be more or less compatible between the two studies – indeed the Jarmans appear to have been more optimistic than the present writer. Matters are complicated in the case of Evans1 by damage inflicted as a result of transportation (above 5.2.1). How this may have affected identifiability, and therefore selective discard of specimens by the Jarmans, is explored here by looking at fragmentation patterns (excluding fresh breaks). Because patterns of breakage are likely to differ between both different body parts and different taxa, analysis of fragmentation is restricted to long bones and is conducted separately for cattle, pigs and sheep/goat[2].

In order to control for potential spatial differentiation in fragmentation of Neolithic material, only bone groups from the CC are used (the main focus of the Evans1 excavation), and material from both Evans campaigns is divided into 'Early' (Strata IIIb-X, Aceramic-MN) and 'Late' (Strata IIIa-II, LN). For the 'Early' sub-group, it is suggested that the Jarmans selectively discarded specimens not regarded as identifiable; BA material excavated by Hood, from various areas, is also tabulated for comparative purposes.

[2] The analytical reasons for which other taxa identified are excluded from this analysis are detailed in section 5.4.1.

Table 5:2 Frequency of old break types in long bones from Evans1, Evans2 (CC only) and Hood assemblages
(MaxAU; excluding foetal/newborn specimens and loose epiphyses).

		Central Court (Aceramic-MN)		Central Court (LN)		Various areas (BA)
Taxon	Types of fragmentation	Evans1	Evans2	Evans1	Evans2	Hood
Cattle	Whole	6	8	8	19	8
		2%	4%	1%	6%	2%
	End	339	140	627	201	374
		89%	67%	63%	65%	80%
	Shaft splinter	33	52	345	77	76
		8%	25%	34%	25%	16%
	Cylinder	3	9	20	13	10
		1%	4%	2%	4%	2%
	Total	381	209	1000	310	468
Pig	Whole	55	14	52	28	157
		32%	11%	13%	18%	19%
	End	111	85	249	79	507
		64%	67%	61%	52%	62%
	Shaft splinter	6	19	97	25	79
		4%	15%	24%	16%	10%
	Cylinder	0	9	10	21	73
		0%	7%	2%	14%	9%
	Total	167	127	408	153	816
Sheep/ goat	Whole	78	23	31	34	257
		11%	3%	2%	6%	8%
	End	647	478	1078	376	1856
		86%	69%	69%	70%	61%
	Shaft splinter	16	83	322	38	454
		2%	12%	21%	7%	15%
	Cylinder	9	111	125	93	456
		1%	16%	8%	17%	15%
	Total	750	695	1556	541	3023

Table 5:2 shows that cylinders and shaft fragments are under-represented considerably in the 'Early' ('selected') Evans1 material, as preserved now, when compared to Evans2 material of the same chronological range and the same excavation area. The same basic contrast in fragmentation patterns is evident when 'Early' Evans1 material is compared with the 'Late' Evans2 and Hood material. The distinctive composition of the 'Early' Evans1 material is most economically interpreted as a by-product of the damage incurred during transport coupled with selective discard of 'unidentifiable' material: cylinders were reduced to unidentifiable shaft splinters and shaft splinters were further fragmented to the stage of non-identifiability. This, it is suggested, led the analysts to exclude these specimens from analysis and subsequently to discard them. Support for this interpretation arises from consideration of the 'Late' Evans1 material, which, it has been argued, was also subjected to transport damage (cf. the high level of fresh breaks - Table 5:1), but not selective discard. As expected, the retention of freshly broken specimens results in very high

levels of shaft splinters, while intermediate frequencies of cylinders probably reflect the partial success of efforts by the present study to repair fresh breaks.

These conclusions have important implications for the rest of the present analysis. Post-excavation breakage and selective retention of Evans1 Aceramic-MN assemblages means that these bone groups have to be excluded from analyses of fragmentation patterns, as evidence for scavenger attrition or human carcass processing. Taxonomic and elemental representation may also have been at least partially affected. On the other hand, post-cranial age, sex and metrical data may not be affected significantly as they largely derive from 'end' specimens. Butchery marks and pathological traces are also most frequently observed near articulations and so may be admissible as evidence with caution. The limitations posed by the above will be tackled individually in the following sections of data analysis.

While transport damage led to selective loss of certain types of long bone fragments, sorting of the material showed that even fragmentary loose teeth were kept[3]. A bias towards more systematic retention of dental material (as this is highly identifiable even in extremely fragmentary condition) is manifest in the proportion of loose mandibular teeth to mandible specimens (whole or fragmentary) (Table 5:3). In this case, loose teeth are the result of breakage before as well as during or after excavation. Nonetheless, additional breakage during transport should have inflated the proportion of loose teeth in Evans1 material, while selective discard of loose teeth might have obscured such a contrast. In fact, for all three taxa, and for both chronological sub-divisions, the Evans1 material has a higher proportion of loose teeth than does the Evans2. Thus it seems that, whereas minimal effort by the Jarmans to mend fresh breaks led to the discarding of potentially recordable post-cranial material, this was not the case with teeth; the preserved dental assemblage is closer in composition to that originally recovered during excavation. It should be noted, however, that systematic retention of dental material, coupled with selective discard of post-cranial material, poses obvious problems for the analysis of anatomical representation in the 'Early' Evans1 levels.

[3] This was evident from the number of even fragments of loose teeth which were given unique accession numbers.

Table 5:3 Frequencies of mandibles and loose mandibular teeth from 'Early' and 'Late' Evans1 and Evans2 assemblages
(MaxAU; 'Early': Aceramic-MN and Strata IIIb-X; 'Late': LN and Strata II-IIIa).

		Central Court only			
		Early		Late	
Taxon	Element	Evans1	Evans2	Evans1	Evans2
Cattle	Mandibles	61	15	78	55
		24%	37%	20%	39%
	Loose mandibular teeth	195	25	313	87
		76%	62%	80%	61%
	Total	256	40	391	142
Pig	Mandibles	81	20	70	88
		67%	77%	89%	90%
	Loose mandibular teeth	39	6	9	10
		33%	23%	11%	10%
	Total	120	26	79	98
Sheep/ Goat	Mandibles	373	100	292	329
		39%	44%	46%	68%
	Loose mandibular teeth	583	128	337	153
		61%	56%	54%	32%
	Total	956	228	629	482

5.2.2.2 *Winder's study*

In the early 1980s, N. Winder commenced doctoral research at Southampton with the aim of re-analysing the Jarman data for the Neolithic period (i.e. only the material from J.D. Evans' excavations) and re-studying part of the faunal material itself. His project never came to complete fruition, as, firstly, he believed the material from the 1957-60 campaign to have been discarded (Winder 1986: 236) and, secondly, he formed the impression (wrongly, it seems) that storage conditions at Knossos had rendered the 1969-70 material unusable (Winder 1986: 32, 235). As a result, Winder reformulated his research aims and undertook instead a statistical analysis of the data gathered by the Jarmans, together with limited re-study of the material. The former assessed the validity of reported changes in taxonomic composition by analysing body part representation and led Winder to conclude that differences in taxonomic composition between periods were simply a reflection of taphonomic processes (Winder 1986: 145). The latter consisted of a novel method of speciating sheep and goat mandibles, based on differential tooth eruption and wear patterns, in order to investigate management practices for the two taxa, but finally appeared only as an appendix to the overall study. One important implication of this aspect of Winder's study is that, while at Knossos, he apparently sorted dental specimens and bagged those from larger deposits separately, as they were found in the course of my fieldwork. Unfortunately, because only part of the material from Evans2 LN deposits could be recorded within the timeframe of this thesis, it is possible that a disproportionately large number of LN dental specimens was recorded, resulting in over-

representation of mandibles and mandibular teeth in these deposits (below, Chapter 6). This problem will be resolved prior to publication by completion of recording of the remaining material.

With hindsight, Winder's statistical analysis of the Jarman data seems to have been a futile exercise, given the major flaws in their quantification methods. Any patterns observed in his analysis may primarily reflect the Jarmans' quantification method (or lack thereof). Taphonomic processes affect all archaeological material. The severity of such processes for a given assemblage must be explored by analysing relevant variables (e.g., scavenger attrition, fragmentation patterns). The only variables available to Winder were taxon and element representation, both quantified in a manner effectively precluding taphonomic analysis. In the context of the present study, it was concluded that the impact of taphonomic processes on the formation of the Knossos assemblages could only be assessed reliably using more relevant data, derived from re-examination of the material.

5.3 Excavation and recovery methods

5.3.1 Introduction

5.3.1.1 *Hood's excavation campaigns*

Hood at Knossos used the stratigraphic methods pioneered by Wheeler and Kenyon, the latter his teacher at the Institute of Archaeology in the 1940s. He was indeed the first to introduce stratigraphically controlled excavation, at least in British projects (perhaps on the island as a whole), as the director of the British School at Athens (Boardman 1994: xvi). It seems, however, that more systematic methods, employed later for the recovery of bioarchaeological remains, were not practised. Thus, faunal material was hand collected in the trench, apart from one artefact-rich context, the 'Ivory Deposit', which appears to have been dry-sieved.

5.3.1.2 *J.D. Evans' excavation campaigns*

Similar excavation techniques were employed by J.D. Evans, while in his second campaign, more rigorous recovery methods were introduced, in addition to hand-collection in the trench:

> 'during both the 1969 and 1970 seasons both wet and dry sieving and froth flotation was carried out on *extensive samples* of the Neolithic deposits by a team under M.R. Jarman, Assistant Director of the British Academy Major Research Project in the Early History of Agriculture'... 'the main object of this work was the recovery of plant

remains and small bones, the other materials, including pottery were also kept and examined...' (J.D. Evans 1973: 136, emphasis added).

Winder (1986: 82) refers to the above programme as 'detailed sieving studies', citing a personal communication by Gamble who participated in the excavation, and suggests that it targeted the totality of the excavated deposits. Observations in the field during data collection do not support this statement entirely. Although there were bags labelled DS or WS or simply S, presumably containing material from dry-sieving or wet-sieving, these belonged only to the Aceramic to ENII/MN Transition levels. The above qualify J.D. Evans' statement of 'extensive sampling' and suggests that in effect only the earlier periods were targeted for sieving. This is also consistent with the research aims of the Jarmans' team, which worked at Knossos under the umbrella of the British Academy Major Research Project into the Early History of Agriculture project directed by Higgs (Winder 1991: 49). The extent to which these more systematic recovery methods have affected the composition of the assemblage will be investigated below.

5.3.1.3 *Momigliano and Wilson EH 93 excavation campaign*

Momigliano and Wilson appear not to have used intensive recovery methods (i.e. sieving or flotation), apparently not deemed appropriate for the small scale of the excavation.

5.3.1.4 *Implications and analytical approaches adopted by the present study*

Evidently, the research aims and interests of the excavation directors, the methods employed during excavation, and levels of skill of the excavation personnel are crucial variables affecting recovery efficiency of faunal remains, which in turn affects the composition of an assemblage. Unfortunately, due to the time that has elapsed since the first three campaigns were undertaken, detailed information on methods of recovery, and thus the efficiency of recovery, cannot be ascertained directly. For example, no records are available of which Evans2 deposits were subjected to dry and wet sieving and flotation and on what scale; nor is it known what mesh sizes were used by Hood or J.D. Evans.

The following sections explore the impact of partial recovery by comparing anatomical and taxonomic composition of the various sub-assemblages (see Chapter 3 for detailed description of the methodology used). Assemblages collected by hand in the trench – as was the majority of the material under study – should exhibit partial retrieval of small skeletal elements. Thus, third and

second phalanges should be most underrepresented, first phalanges less so, then astragali and calcanea least of all. This pattern should be clearest for sheep/goat and pig and least clear for cattle, the largest common domesticate in the present assemblage. Conversely, the composition of dry- and wet-sieved bone groups should be less biased towards larger-bodied taxa and larger skeletal elements. The analysis of recovery efficiency thus focuses on the frequency in different assemblages of these small elements (calcaneum, astragalus and phalanges) and, as 'controls', of the frequency of the adjacent long bone zones (distal tibia and distal metapodials).

Caution is needed in the case of the 'Early' Evans1 material, as post-excavation damage and discard might have led to the selective removal of the 'control' zones, thus artificially increasing the proportion of the more compact calcanea, astragali and phalanges. On the other hand, this potential bias may be offset by the fact that recovery efficiency is analysed in terms of MinAU, which anyway tends to discount long bone cylinders and shaft fragments, in favour of ends. Table 5:4 compares Evans1 'Early' (selected) and 'Late' (unselected) in terms of both MinAU and percentage of anatomically expected counts (AEC%), treating distal tibia and distal metapodials as 100%.

Table 5:4 Recovery efficiency in Evans1 'Early' and 'Late'
(MinAU; MDT only; relative frequencies of adjacent large and small bones in ankle and foot).

		Evans1			
		'Early' (Strata IIIb-X)		'Late' (Strata II-IIIa)	
Taxon		MinAU	AEC%	MinAU	AEC%
Cattle	Td	58	100	72	100
	C	61	105	77	107
	A	87	150	59	82
Pig	Td	29	100	41	100
	C	36	129	49	120
	A	18	64	25	61
Sheep/ goat	Td	253	100	320	100
	C	75	30	100	31
	A	92	36	63	20
Cattle	MPd	151	100	172	100
	PH1	231	153	265	154
	PH2	195	129	256	149
	PH3	141	93	228	133
Pig	MPd	50	100	56	100
	PH1	25	50	46	82
	PH2	7	14	24	43
	PH3	4	8	15	27
Sheep/ Goat	MPd	248	100	332	100
	PH1	72	29	149	45
	PH2	11	4	16	5
	PH3	6	2	19	6

The table shows that the frequency of cattle and sheep/goat astragali is considerably higher in Evans1 'Early', but cattle third and sheep/goat first phalanges and all pig phalanges are much more abundant in Evans1 'Late'. The possibility that selective curation and/or discard in antiquity have

contributed to this result will be further explored in later sections. At this stage, it should be noted that Evans1 'Early' does not appear to be biased in a manner seriously affecting assessment of recovery and so can be used in the following discussion along with the rest of the Evans1 assemblage.

5.3.2 Recovery efficiency in unsieved Knossos assemblages

Table 5:5 below lists MinAUs and percentages of anatomically expected counts (AEC%) for ankle and foot bones of the three dominant taxa. The data are presented both separately and combined for those bone groups of the three campaigns believed to have been recovered without sieving: Evans1 (all), Evans2 'Late' (here MN, LN and EMII), and Hood (excluding the sieved 'Ivory Deposit'). For the sake of completeness, MinAU values are also presented for the Momigliano and Wilson campaign (also unsieved), but this assemblage is not discussed, nor AEC% computed, as its small sample size precludes meaningful analysis.

Table 5:5 Recovery efficiency in unsieved assemblages
(MinAU; MDT only; relative frequencies of adjacent large and small bones in ankle and foot).

		Excavators/Campaigns							
		Evans1 (all phases)		Evans2 (MN, LN & EMII only)		Hood (all phases)		Momigliano and Wilson (all phases)	All unsieved assemblages combined
Taxa	Elements	MinAU	AEC%	MinAU	AEC%	MinAU	AEC%	MinAU	AEC%
Cattle	Td	130	100	101	100	29	100	1	100
	C	138	106	119	118	50	172	1	118
	A	146	112	90	89	78	269	2	121
Pig	Td	70	100	43	100	59	100	0	100
	C	85	123	41	95	39	66	2	97
	A	43	62	14	33	30	51	0	51
Sheep/ goat	Td	573	100	361	100	373	100	16	100
	C	175	31	77	21	155	42	8	31
	A	155	27	52	14	98	26	5	23
Cattle	MPd	323	100	250	100	106	100	3	100
	PH1	496	153	298	119	137	129	5	137
	PH2	451	140	182	73	93	88	4	107
	PH3	369	114	188	75	40	38	1	88
Pig	MPd	106	100	62	100	104	100	1	100
	PH1	71	67	32	52	41	39	0	53
	PH2	31	29	5	8	12	12	0	18
	PH3	19	18	6	10	2	2	0	10
Sheep/ goat	MPd	580	100	363	100	333	100	14	100
	PH1	221	38	127	35	106	32	4	35
	PH2	27	5	24	7	10	3	0	5
	PH3	25	4	16	4	9	3	0	4

χ^2 tests for combined unsieved assemblages	Td/C/A		MPd/Ph1-3	
	χ^2	p	χ^2	p
Cattle-Pig	33.312	0.000	255.124	0.000
Pig-Sheep/Goat	94.984	0.000	55.149	0.000
Cattle-Sheep/Goat	316.528	0.000	1203.359	0.000

For all three assemblages combined, small bones of the medium-sized domesticates are poorly represented (pigs less so than sheep/goats), whereas small bones of cattle are close to expected

counts. Moreover, within each medium-sized taxon, progressive reduction in recovered specimens is observed from the larger calcanea to the smaller second and third phalanges. In the case of sheep/goats especially, a dramatic reduction can be seen in the numbers of specimens recovered from the larger first phalanx to the smaller second and third phalanges. On the contrary, for the large-bodied cattle, the larger elements, calcanea, astragali and first phalanges, are over-represented in comparison to their adjacent long bone articulations (distal tibia and distal metapodial) and only the third phalanges are clearly underrepresented. χ^2 tests suggest highly significant differences in efficiency of recovery, not only between cattle and pig, and cattle and sheep/goat (for both ankle and foot bones) but even between pig and sheep/goat (Table 5:5). Thus, both the anatomical and taxonomic composition of the assemblage have been affected by partial recovery.

As discussed in 5.3.1, the assemblage was recovered over some forty years during four different excavation campaigns. Different projects have targeted different areas and, in some cases, different periods with different research agendas. Consequently, it is important to establish whether these separate campaigns achieved similar standards of retrieval.

When the different hand-collected assemblages are compared, some discrepancies are evident: for example, pig astragali are relatively scarce in Evans2 'Late', pig calcanea and cattle third phalanges in Hood, but cattle calcanea and astragali are strikingly over-represented in Hood. These anomalies may reflect irregularities in bone discard, while high frequencies of cattle phalanges in Evans1 may be an artefact of differential survival of transport to Britain. There is no evidence, however, that the standard of hand retrieval differed consistently between campaigns; on the contrary, each assemblage repeats the overall pattern of a decrease in the number of specimens from the larger bodied cattle to the smaller bodied sheep/goats and from the largest calcaneum and astragalus to the smallest second and third phalanges.

It might be argued that consistent differences in hand-retrieval efficiency are not apparent because different campaigns to some extent focussed on deposits of different date and so perhaps contrasting taphonomic history. To contrast hand-recovery by J.D. Evans and Hood, Table 5:6 compares the EMII sub-assemblages from Hood's RR and PEM excavations and from the Evans2 work in the WC, thus restricting analysis to material of the same date. The former is certainly unsieved and the latter likewise if the evidence of bag labels reviewed above, is reliable. Because of the small number of the Hood cattle and pig and Evans2 pig remains, analysis is restricted to the more numerous sheep/goat remains. These present a contradictory picture: while Evans2 was apparently more successful in retrieving second phalanges (highly significantly) and third phalanges

(significantly), Hood appears to have been considerably more efficient in recovering astragali (significantly) and calcanea (highly significantly) (Table 5:6). Thus there is again no consistent evidence of differences between excavators in the efficiency of hand recovery, while earlier suggestions of irregularities in bone discard receive some further support.

Table 5:6 Recovery efficiency in EMII deposits
(MinAU; MDT only; relative frequencies of adjacent large and small bones in ankle and foot).

Taxa	Elements	West Court EMII (Evans2)		Royal Road/PEM EMII (Hood)	
		MinAU	AEC%	MinAU	AEC%
Cattle	Td	9	100	0	-
	C	19	211	7	-
	A	10	111	3	-
Pig	Td	8	100	1	100
	C	4	50	2	200
	A	4	50	1	100
Sheep/goat	Td	93	100	54	100
	C	12	13	28	52
	A	19	20	26	48
Cattle	MPd	31	100	3	100
	PH1	36	116	2	67
	PH2	22	71	0	0
	PH3	12	33	2	100
Pig	MPd	4	100	2	100
	PH1	8	200	4	200
	PH2	3	75	1	50
	PH3	0	0	0	0
Sheep/goat	MPd	81	100	54	100
	PH1	35	43	12	22
	PH2	12	15	0	0
	PH3	8	23	0	0

	Evans2 WCH and Hood RR & PEM (EMII contexts)									
	Td & C		Td & A		MPd & PH1		MPd & PH2		MPd & PH3	
	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p
Cattle	3.029	0.082	2.405	0.121	0.352	0.553	2.051	0.152	0.317	0.573
Pig	1.111	0.292	0.207	0.649	0.000	1.000	0.079	0.778	-	-
Sheep/goat	14.132	0.000	6.277	0.012	3.157	0.076	7.587	0.006	5.142	0.023

5.3.3 Recovery efficiency in sieved Knossos assemblages

If the hand collected assemblages from Knossos exhibit the expected patterns of taxonomic and elemental under-representation, is there any evidence that sieving resulted in improved recovery efficiency? Hood's sieved LMIB 'Ivory Deposit' is compared in Table 5:7 with unsieved Hood deposits of the same date.

Table 5:7 Recovery efficiency in LMIB deposits
(MinAU; MDT only; relative frequencies of adjacent large and small bones in ankle and foot).

		Ivory Deposit		Other LMIB deposits combined	
Taxa	Elements	MinAU	AEC%	MinAU	AEC%
Cattle	Td	1	100	2	100
	C	2	200	4	200
	A	2	200	11	550
Pig	Td	6	100	12	100
	C	5	83	9	75
	A	3	50	6	50
Sheep/goat	Td	28	100	49	100
	C	11	39	23	47
	A	16	57	29	59
Cattle	MPd	3	100	18	100
	PH1	7	233	23	128
	PH2	4	133	11	61
	PH3	3	100	5	28
Pig	MPd	23	100	23	100
	PH1	11	48	8	35
	PH2	4	17	4	17
	PH3	2	9	0	0
Sheep/goat	MPd	39	100	60	100
	PH1	30	77	27	45
	PH2	10	26	3	5
	PH3	3	8	3	5

	Hood LMIB contexts: 'Ivory Deposit' vs. LMIB other									
	Td & C		Td & A		MPd & PH1		MPd & PH2		MPd & PH3	
	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p
Cattle	0.000	1.000	0.515	0.473	0.641	0.423	0.856	0.355	1.903	0.168
Pig	0.020	0.888	0.000	1.000	0.336	0.562	0.000	1.000	1.920	0.166
Sheep/goat	0.166	0.683	0.008	0.929	2.570	0.109	6.577	0.010	0.265	0.607

Comparison of Hood's sieved 'Ivory Deposit' with his other LMIB deposits is problematic because sample size is very small for both ankle and foot bones of cattle and for ankle of pig; analysis is thus effectively restricted to sheep/goat and to foot bones of pig. A statistically significant differences is observed only in the case of second phalanx (highly significant) of sheep/goats (Table 5:7), but the 'Ivory Deposit' has higher AEC% of pig and sheep/goat phalanges. Nonetheless, recovery rates for the smaller second and third phalanges are still low for the sieved 'Ivory

Deposit'. In this case, therefore, it seems that sieving improved recovery efficiency, but not dramatically. The possibility of an extremely coarse mesh can be excluded, as personal observation of the recovered 'ivory' fragments (several smaller than 1cm) suggests the use of a fine mesh. It could be argued that the 'Ivory Deposit' was sieved primarily to recover artefacts and what was thought to be ivory working debris, thus putting less emphasis on the retrieval of animal bone. It is also possible that sheep/goat phalanges were originally underrepresented in this particular deposit.

Evans2 practised both dry and wet sieving, but it was argued above that these recovery methods were only used in Aceramic-EN/MN transition levels. Table 5:8 thus compares the Evans2 'Early' levels with both the selectively discarded Evans1 material of the same date and the Evans2 'Late' assemblage.

Table 5:8 Recovery efficiency in sieved, unsieved and selected material from Evans' campaigns (MinAU; MDT only; relative frequencies of adjacent large and small bones in ankle and foot).

		Evans2				Evans1	
		Aceramic-EN/MN Trans (sieved)		MN-LN-EMII (unsieved)		'Early' – Stratum IV-X (unsieved-selected)	
Taxon	Element	MinAU	AEC%	MinAU	AEC%	MinAU	AEC%
Cattle	Td	54	100	101	100	18	100
	C	51	94	119	118	21	117
	A	45	83	90	89	47	261
Pig	Td	10	100	43	100	15	100
	C	24	240	41	95	27	180
	A	10	100	14	33	13	87
Sheep/goat	Td	215	100	361	100	167	100
	C	54	25	77	21	65	39
	A	33	15	52	14	78	47
Cattle	MPd	157	100	250	100	76	100
	PH1	132	83	298	119	105	138
	PH2	94	60	182	73	105	138
	PH3	65	50	188	75	67	88
Pig	MPd	23	100	62	100	39	100
	PH1	23	100	32	52	17	44
	PH2	10	43	5	8	7	18
	PH3	8	35	6	10	3	8
Sheep/goat	MPd	307	100	364	100	182	100
	PH1	109	36	127	35	65	36
	PH2	43	14	24	7	11	6
	PH3	15	5	16	4	5	3

The samples from sieved 'Early' Evans2, probably unsieved 'Late' Evans2 (Table 5:8) and definitely unsieved 'Early' Evans1 are much larger and allow a fuller analysis than was possible for Hood's material. With the exception of sheep/goat first phalanges, 'Early' Evans2 exhibits higher AEC% than either 'Early' Evans1 or 'Late' Evans2 for all phalanges of pig and sheep/goat; in most cases, the figures for 'Early' Evans2 are *much* higher. This pattern is consistent with improved recovery thanks to sieving in 'Early' Evans2 and, together with Table 5:5, supports the argument that 'Late' Evans2 was not sieved to any significant degree, if at all. On the other hand, it must be

acknowledged that improved recovery in 'Early' Evans2 is only apparent for the smallest body parts (pig and sheep/goat phalanges) and that, even for these, recovery remains poor. Perhaps sieving was not conducted thoroughly enough or on a large enough scale to make a considerable difference. Other post-depositional processes may also have affected the composition of the assemblages prior to excavation – a possibility explored in section 5.4.

The evident concentration of Evans2 sieving in the early phases is consistent with the research agenda of the Jarmans, who were present on site. This then raises the possibility that recovery may have been more intensive within 'Early' Evans2 in the lowest levels. To explore this possibility, Table 5:9 breaks down 'Early' Evans2 into its constituent sub-phases; in this case, MaxAU data are presented because the relative frequencies of different taxa or body parts are not compared.

Table 5:9 Recovery efficiency in sieved assemblages from Evans2 'Early' deposits.

	Aceramic	ENIa	ENIb	ENIc	ENII	ENII/MN Trans	Total
MaxAU recovered in sieve	46	0	93	53	153	11	356
% MaxAU recovered in sieve	6.5%	0%	10.5%	16.5%	6.6%	2.2%	7.4%
% Calcanea recovered in sieve	2.2%	0%	1.1%	0%	2.6%	0%	2%
% Astragali recovered in sieve	0%	0%	0%	0%	0.7%	0%	0.3%
% Phalanges 1-3 recovered in sieve	67.4%	0%	20.4%	20.8%	22.2%	45.5%	28.1%
Total recovered	705	91	886	321	2317	501	4821

The contribution of sieving to bone groups of early phases ranged from 0% to 16.5% for all taxa and body parts combined. The absence of sieved bone in ENIa might be attributable to chance variation in small samples. The low figure for the ENII/MN Transition (2.2%), however, is based on a larger sample and suggests that sieving may have been less rigorous or, perhaps more likely, less frequent in the upper levels. This is plausible because, with the benefit of the Evans1 campaign, the excavators were obviously able to recognise when EN deposits (of particular interest to the Jarmans) were reached. For the same reason, however, it is plausible that the earliest deposits were subjected not only to more rigorous recovery methods, but also to more meticulous excavation. If so, the modest contribution of sieving to bone recovery for the Aceramic (6.5%), contrasting with the peak in ENIb-c (10.5-16.5%), might reflect improved recovery during excavation rather than less rigorous sieving of the lowest levels that would have interested the Jarmans most. This interpretation is strongly supported by the fact that most of the bones recovered in the sieve from Aceramic deposits were sheep/goat phalanges, most of which were fragmentary. In the following EN and EN/MN Transition levels, sieving yielded a broader range of body parts suggesting less thorough collection in the trench. This in turn reinforces the argument that the declining proportion of sieved bone in ENII (6.6%) and EN/MN Transition (2.2%) deposits reflects a decreasing frequency or intensity of sieving in the upper levels.

Whether or not the intensity or frequency of sieving were comparable in the CC and the WC trenches cannot be assessed: when the Evans2 'Early' deposits are divided by area and into sub-phases, individual samples are too small for meaningful comparison. The indirect evidence of bags labelled 'WS', 'DS' or 'S', however, implies that the same chronological range of deposits was sieved in both the CC and WC.

5.3.4 Conclusion

The following generalisations can be made concerning retrieval efficiency at Knossos:

- Components of the assemblage known or believed to be unsieved (Evans1, 'Late' Evans2, Hood excluding the 'Ivory Deposit') exhibit the expected under-representation of smaller specimens. Retrieval of small ankle (calcaneum and astragalus) and foot (phalanges) bones is good for cattle, but poor for pig and sheep/goat; the smallest bones (second and third phalanges) of pig and sheep/goat are most strongly under-represented.
- Components of the assemblage believed to have been sieved ('Early' Evans2 and Hood 'Ivory Deposit') exhibit improved recovery of small foot bones of pig and sheep/goat. Improvements appear to be marginal, however, so that all sub-assemblages should be treated as subject to partial recovery. The modest gains from sieving can probably be attributed to a combination of partial application, large mesh size, the difficulty of scanning dry-sieved residues and insufficient supervision of sievers.
- There is some evidence that, within the 'Early' Evans2 assemblage, deposits of the later phases (ENII and, especially, ENII/MN Transition) were subjected to less intensive or less frequent sieving while, conversely, the earliest Aceramic level benefited from especially meticulous retrieval *in the trench*. Although the efficiency of unsieved hand recovery is likely to have been variable, there is no evidence of a consistent difference between excavation campaigns.
- Some inconsistencies in the previous analyses, for example the unexpectedly high frequency of cattle calcanea and astragali in the unsieved Hood assemblage, raise the possibility of temporal and spatial variability in bone discard and/or survival.

These observations have certain implications for subsequent analysis. Since the assemblage has been affected by partial recovery, extreme caution should be exercised in interpreting under-representation of the smallest elements, especially phalanges of pig and sheep/goat. These small elements are subject to improved retrieval in the 'Early' Evans2 material and the small Hood 'Ivory Deposit' and are probably most vulnerable to inevitable variation in hand retrieval; for this reason,

it may be advisable to exclude phalanges, astragali and calcanea from assessment of taxonomic composition in different sub-assemblages. Otherwise, the composition of different sub-assemblages has not been seriously affected by differential recovery, thus making the assemblages comparable for most analytical purposes. Some unexpected patterns, such as the over-representation of cattle astragali and calcanea in Hood, need to be explored below in terms of differential survival or, perhaps, discard.

5.4 Post-depositional filters

5.4.1 Introduction

Before beginning discussion of the post-depositional processes which have affected the assemblage, the arguments for the faunal remains having been deposited by humans will be briefly presented. All animal bones present in archaeological deposits at Knossos derive from taxa originally introduced to Crete by humans, based on palaeontological and biogeographical evidence (Chapter 2). Some of the arguably intentionally introduced species, e.g., badgers and martens, and the perhaps accidentally introduced rodents, became feral and are still extant on the island. Their behavioural habits mean that they are likely to have disturbed archaeological deposits at Knossos in recent times and to have contributed to the deposition of some of the faunal remains recovered, either by introducing bones of animals on which they prey, or becoming incorporated in the deposits themselves when dying in dens and burrows. Thus, an assessment is required of the status of the remains based on direct evidence.

That the deposits at Knossos are overwhelmingly derived from human activity is evidenced by architectural remains and movable artefacts. The bones themselves clearly indicate that most were introduced to be consumed by humans: the vast majority of the specimens were disarticulated, while fragmentation patterns in many cases suggest processing for within-bone nutrient extraction; plentiful evidence was also observed of other stages of carcass processing and exploitation, including butchery marks and bone working (Chapter 6). Such observations are abundant for ovicaprids (sheep, goats), pigs, cattle and deer. Butchery marks on bones of dogs and badgers suggest that at least some individuals of these species were processed and deposited by humans.

There are, however, isolated elements of burrowing or den-building taxa, such as badgers, martens, foxes and rodents, which do not bear any of these anthropogenic traces, and so could belong to individuals consumed by other carnivores or which suffered natural deaths and whose skeletons were dispersed by later disturbance. Given that habitation of the site was continuous over several millennia, and that the material in the present study derives mostly from areas where archaeological

strata accumulated vertically, the status of such remains may be assessed on the basis of their stratigraphic position within the Knossos tell mound. This more detailed analysis needs to be undertaken in the future, when a more detailed study of the stratigraphy is available.

5.4.2 Surface erosion and weathering

Visual inspection of material from all periods and contexts showed that weathering and soil chemical processes are unlikely to have played any major role in the transformation of the faunal material, since surface preservation ranged from moderate to very good. The only group exhibiting high levels of erosion (of unknown cause) was that recovered from WCH. These specimens are not included in the analysis of frequency of attrition.

5.4.3 Trampling

Trampling by humans and other animals may cause fragmentation of bones, potentially to the point of non-retrieval or non-identifiability, but there is little actualistic research on recognition of the effect of trampling on faunal assemblage composition (Lyman 1994: 380). The generally good surface preservation of Knossos material perhaps argues against a major taphonomic role for trampling. Compact bones of large taxa should logically be less vulnerable than flat bones of small taxa (Lyman 1994: 379-80) and, by extension, articulations of long bones should arguably be less vulnerable than shafts. In the light of these highly generalised expectations, the possible impact of trampling is considered very briefly in the following section.

5.4.4 Scavenger attrition

5.4.4.1 *Introduction: aims and analytical procedures*

This section analyses evidence for scavenger attrition, but only in so far as it allows an assessment of the degree to which this has affected the composition of the assemblage. Further insights from this evidence will be discussed in other relevant sections. As detailed in Chapter 4, scavenger attrition is gauged in the present study in terms of: a) *frequency* and b) *severity*. Frequency is assessed in terms of physical manifestation of attack by scavengers, i.e. gnawing marks and signs of ingestion on individual specimens. Severity is assessed in terms of two variables: the survivorship of anatomical zones of sheep/goats using Brain's (1981) modern study as a comparative tool; and fragmentation patterns – more specifically, the proportion of complete to fragmentary specimens and the proportion of fragments in the shape of cylinders to those preserving part or complete articular ends (cf. Binford 1981).

For the purposes of the present analysis, data are initially divided into three broad chronological horizons – the Neolithic, Prepalatial and Palatial periods. This division is informed by our understanding of changes that the site underwent over the millennia – most importantly, in terms of spatial organisation. Finer sub-divisions (spatial and temporal) are analysed, where sample size permits, to explore whether the three broader periods are internally homogeneous or heterogeneous.

Only specimens of the MDT are included in the analysis, since, as noted above (5.4.1), some of the other taxa identified may not have been introduced to the site by humans. In practice, whether included or not, these taxa are represented by too few specimens to affect the analysis (Table 5:10).

Table 5:10 Frequencies of taxa identified in the analysed assemblage (MinAU).

Equid	Cattle	Pig	Sh/Gt	Red/Fallow Deer	Red Deer	Fallow Deer	Hare	Total
3	8744	4529	18143	2	2	21	2	
<0.1%	27.6%	14.3%	57.2%	<0.1%	<0.1%	0.1%	<0.1%	
Dog	**Fox**	**Cat**	**Badger**	**Marten**	**Small Carnivore**	**Tortoise**	**Small Rodent**	**31691**
140	2	3	91	2	3	2	2	
0.4%	<0.1%	<0.1%	0.3%	<0.1%	<0.1%	<0.1%	<0.1%	

Finally, the possibility must be considered that selective discard of long bone shaft and cylinder fragments from 'Early' Evans1, may have deflated the frequency of gnawing. Since shaft cylinders are most typical of attack by scavengers, their loss may be expected to reduce the frequency of gnawing. Contrary to predictions, however, 'Early' Evans1 tends to exhibit higher frequencies of gnawing than material from the same phases and the same area (Central Court) excavated by Evans2 (Table 5:11 and Figure 5:1)[4]. In fact, the frequency of gnawing in Evans1 CC tends to fall between that for Evans2 CC and Evans2 WC, suggesting contextual variation in carnivore attrition rather than an artefact of post-excavation damage. The Evans1 material is usable in the analysis of gnawing frequency, therefore, but will be excluded from the analysis of severity of gnawing, as both anatomical representation and fragmentation patterns are likely to have been affected by modern breakage and discard.

[4]The causes of contrasts with the West Court, an area excavated only by Evans2, are discussed in section 5.4.5.2.

Table 5:11 Frequency of gnawing in Neolithic sub-phases in the CC and WC (MaxAU; MDT only; excluding loose teeth and newborn/foetal specimens).

		Str10	Str9	Str8	Str7	Str6	Str5	Str4	Str3b	Str3a	Str2
Evans1 Central Court	No Gnawing	189	121	138	184	532	292	503	1230	793	4737
		88%	**86%**	**78%**	**69%**	**70%**	**68%**	**78%**	**73%**	**75%**	**76%**
	Gnawed	26	19	40	82	230	136	141	445	263	1493
		12%	**14%**	**23%**	**31%**	**30%**	**32%**	**22%**	**27%**	**25%**	**24%**
		Aceramic	**ENIa**		**ENIb**		**ENIc**	**ENII**	**MN**		**LN**
Evans2 Central Court	No Gnawing	574	67		114		71	216	751		2189
		89%	**80%**		**78%**		**56%**	**81%**	**81%**		**83%**
	Gnawed	70	17		33		56	52	174		449
		11%	**20%**		**22%**		**44%**	**19%**	**19%**		**17%**
Evans2 West Court	No Gnawing				373		97	1249	1403		974
					55%		**61%**	**66%**	**76%**		**77%**
	Gnawed				306		61	636	434		289
					45%		**39%**	**34%**	**24%**		**23%**

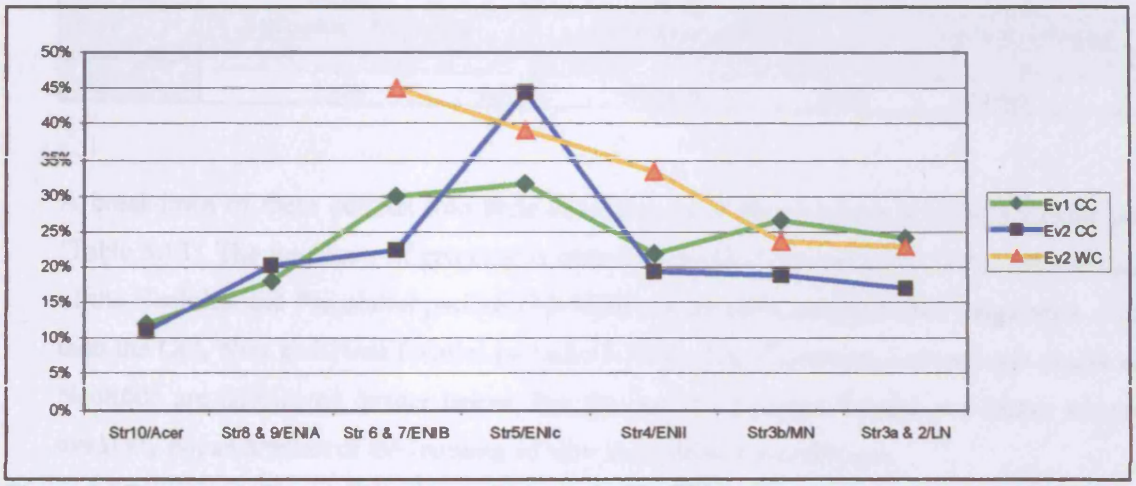


Figure 5:1 Frequency of gnawed specimens through the Neolithic (data from Table 5:11).

5.4.4.2 *Frequency of scavenger attrition*

Table 5:12 lists MaxAU of MDT specimens exhibiting signs of modification by scavengers and shows that the frequency of attrition is much higher in Neolithic and Prepalatial than Palatial sub-assemblages; the differences are statistically highly significant.

Table 5:12 Frequency of gnawing for Neolithic, Prepalatial and Palatial periods (MaxAU; MDT only; excluding loose teeth and newborn/foetal specimens).

	Neolithic		Prepalatial		Palatial	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	17195	75.6	2328	77.0	4920	91.4
Gnawed	5561	24.4	696	23.0	463	8.6
Total	22756		3024		5383	
	Neolithic – Prepalatial		Prepalatial – Palatial		Neolithic – Palatial	
χ^2 test values	χ^2	p	χ^2	p	χ^2	P
	2.935	0.087	338.500	0.000	649.645	0.000

A breakdown of these periods into their constituent sub-phases shows a broadly similar pattern (Table 5:13). The frequency of gnawing is quite low in the Aceramic (only 11%). All other phases of the Neolithic and Prepalatial periods (19-35%) exhibit substantially higher frequencies of attack than the Old, New and Final Palatial periods (8-14%). The differences between sub-phases of the Neolithic are considered further below, but the contrast between Palatial and earlier material is evidently not an artefact of the lumping of very variable sub-assemblages.

Table 5:13 Frequency of gnawing by sub-phases of Neolithic, Prepalatial and Palatial periods (MaxAU; MDT only; excluding loose teeth and newborn/foetal specimens; in brackets, Evans1 strata).

	Neolithic								Prepalatial		Palatial		
	Aceramic (X)	ENIa (IX-VIII)	ENIb (VI-VII)	ENIc (V)	ENII (IV)	ENII/MN Transition	MN (IIIb)	LN (IIIa & II)	EMI/II	EMIII-MMIA	Old Palace MMIB-MMIIA	New Palace MMIIB-LMI	Final Palace
Non-gnawed	764	327	1205	460	1991	370	3385	8693	1316	1012	559	3806	559
Gnawed	96	76	650	253	833	107	1052	2494	465	231	54	317	92
% Non-gnawed	89	81	65	65	70	78	76	78	74	81	91	92	86
% Gnawed	11	19	35	35	30	22	24	22	26	19	9	8	14

As different MDT may be processed for human consumption in different ways, and so may be more or less attractive to scavengers, frequency of modification is also analysed by taxon. Table 5:14 shows that levels of attrition are also higher (highly significantly so) in the Neolithic and Prepalatial

than in the Palatial period for the individual MDT. In addition, in the case of cattle only, gnawing is highly significantly more frequent in the Neolithic than Prepalatial period.

Table 5:14 Frequency of gnawing by taxon for Neolithic, Prepalatial and Palatial periods (MaxAU; MDT only; excluding loose teeth and newborn/foetal specimens).

		Cattle		Pig		Sheep/Goat	
		MaxAU	%	MaxAU	%	MaxAU	%
Neolithic	Non-gnawed	5939	77	1972	68	9284	76
	Gnawed by Scavenger	1764	23	917	32	2880	24
	Total	7703		2889		12164	
Prepalatial	Non-gnawed	402	85	298	73	1628	76
	Gnawed by Scavenger	70	15	113	27	513	24
	Total	472		411		2141	
Palatial	Non-gnawed	724	90	1080	89	3116	92
	Gnawed by Scavenger	77	10	128	11	258	8
	Total	801		1208		3374	
Frequency of Scavenger Attrition		Neolithic		Prepalatial		Palatial	
		χ^2	p	χ^2	p	χ^2	p
Cattle-Pig		86.866	0.000	21.444	0.000	0.508	0.476
Pig-Sheep/goat		80.500	0.000	2.325	0.127	10.030	0.002
Cattle-Sheep/goat		1.587	0.208	18.599	0.000	3.391	0.066
		Cattle		Pig		Sheep/Goat	
		χ^2	p	χ^2	p	χ^2	p
Neolithic-Prepalatial		16.643	0.000	3.023	0.082	0.081	0.775
Neolithic-Palatial		75.519	0.000	200.446	0.000	421.108	0.000
Prepalatial- Palatial		7.915	0.005	69.112	0.000	289.889	0.000

Although overall frequencies of gnawing are fairly similar for the three MDT, there are also statistically highly significant differences between cattle and pig, between cattle and sheep/goat and between pig and sheep/goat within individual periods. Thus, differences between taxa are not solely related to body size, while the observed temporal patterning suggests that, over time, individual MDT may have been subjected to distinctive forms or contexts of discard, in turn possibly related to distinctive forms of carcass processing or contexts of consumption.

5.4.4.3 *Severity of attrition*

5.4.4.3.1 *Sheep/goat anatomical representation*

In Figure 5:2 anatomical representation of sheep/goats is shown in terms of the rank order observed by Brain in a modern goat assemblage subject to attrition by dogs. The Neolithic assemblage from Knossos is sub-divided into three groups of phases showing similar frequencies of gnawing: Aceramic, ENIa-ENII and EN/MN Transition-LN. Bronze Age sub-assemblages are divided into Prepalatial and Palatial. To aid interpretation, small body parts, prone to loss in excavation, are highlighted.

The frequency of anatomical zones of sheep/goats in the Prepalatial sub-assemblage matches fairly well Brain's ethnographically observed example, as the number of MinAU decreases from top to bottom, i.e. from more to less robust skeletal elements, implying that scavenger attrition was a decisive factor in the formation of the ovicaprid assemblage dating to this period. Conversely, the frequency of anatomical zones in Palatial deposits differs dramatically from that in Brain's ethnographic example, with most fairly equally represented, showing that scavengers did not seriously affect the elemental composition of most bone groups of this period. For the Neolithic, the combined ENIa-ENII (19-35% gnawing) and EN/MN Transition-LN (22-24% gnawing) groups again broadly match the Brain model. Conversely, the Aceramic exhibits a relatively even anatomical representation consistent with the relatively low frequency of gnawing (11%).

The quantification method used by Brain is different to that employed by the present study, perhaps resulting in the higher frequencies of, for example, proximal tibia at Knossos. Moreover, the frequency of phalanges is inflated in the Aceramic by improved recovery (see above). Nonetheless, comparison with Brain's model suggests a reasonably close relationship, in the case of sheep/goats, between frequency and severity of carnivore attrition.

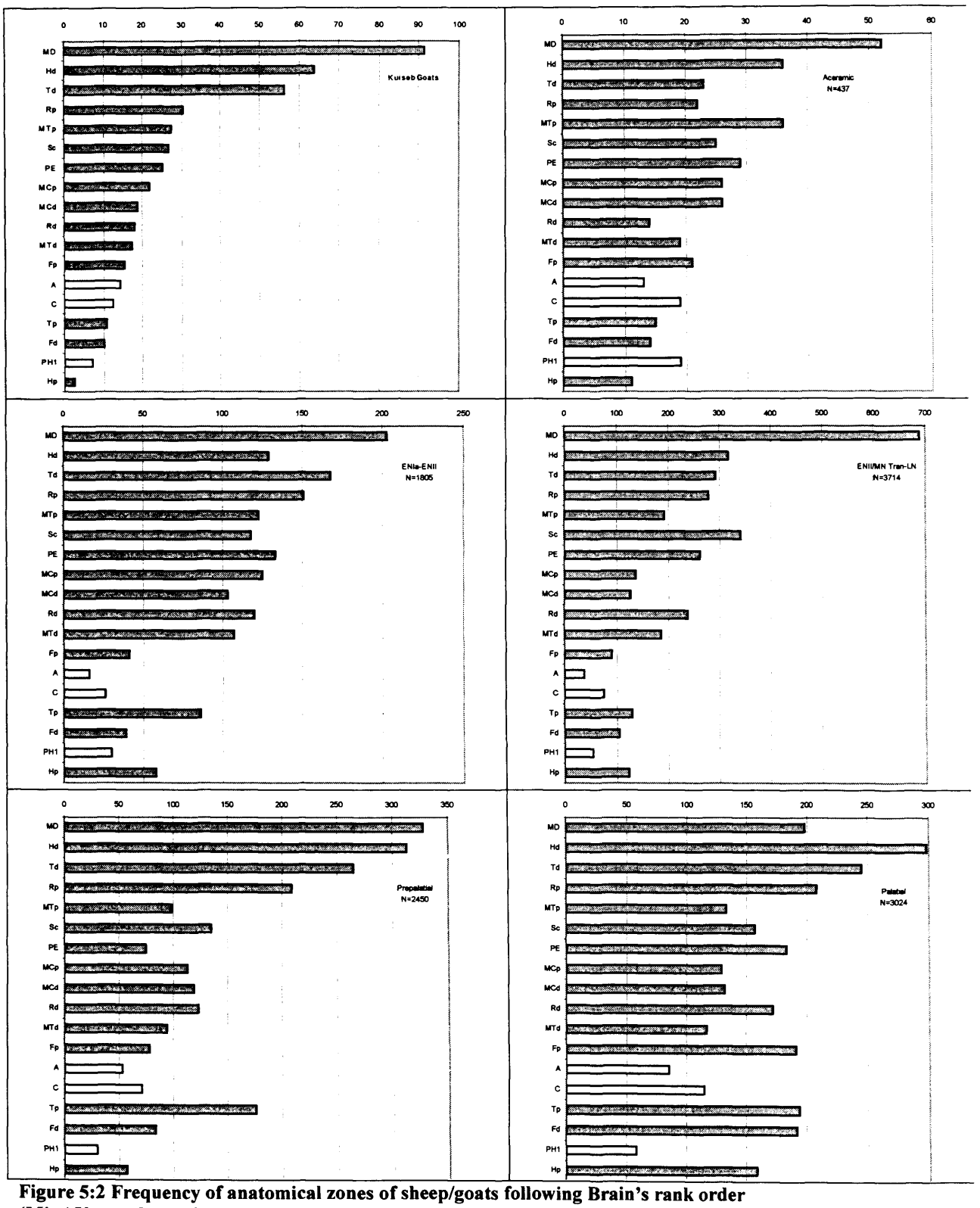


Figure 5:2 Frequency of anatomical zones of sheep/goats following Brain's rank order (MinAU; numbers of phalanges halved; white bars: elements most prone to loss in recovery).

5.4.4.3.2 *Fragmentation patterns*

The analysis of fragmentation patterns allows the severity of carnivore attrition to be assessed for all the MDT, but is complex because bones may be broken as a result of human processing, scavenger attrition or trampling, usually in that order of occurrence. Indeed, although the frequency of gnawed bone at Knossos ranges on average between ca. 9% (Palatial) and ca. 24% (Neolithic and Prepalatial), the proportion of bones with old breaks ranges between the much higher levels of 87% (Palatial) and 93-97% (Neolithic and Prepalatial), suggesting that carnivore attrition is only one (and perhaps not the most important) agent of bone breakage.

To some extent, different agents of breakage can be distinguished by patterns of fragmentation. First, carnivore attrition tends to produce long bone 'cylinders' and 'shaft splinters', while human carcass processing for within-bone nutrients tends to produce long bone 'ends' (or 'end splinters') and 'shaft splinters'; it was tentatively suggested above that trampling might produce a similar signature to human carcass processing. Secondly, carnivore attrition should have less impact on the large and robust bones of cattle than on the smaller bones of sheep/goats and pigs, and less impact on sheep/goats than on pigs, because the latter tended to be culled at a younger age (below Chapter 7). Conversely, the benefits of breaking bones open for marrow tend to be greater in the case of larger and older animals (below Chapter 6). In terms of differential impact on the MDT, trampling probably resembles carnivore attrition, rather than human marrow extraction, in having most effect on bones of small animals. Although the focus of this section is on fragmentation by carnivores, it is important to establish if and how prior processing by humans has affected the fragmentation patterns observed.

Table 5:15 shows that complete long bones of cattle are much rarer than those of pig and (with the exception of the Prepalatial period) sheep/goats. The differences between taxa are statistically highly significant and do not match either the frequency of gnawing (pigs have the highest frequency of gnawing and the highest proportion of complete long bones), or relative vulnerability to carnivore attrition (cattle are most robust and have the lowest proportion of complete long bones, pigs have the highest proportions of both complete long bones and vulnerable young individuals). The rarity of complete cattle bones is thus most economically explained as a result of human processing. Further implications of this observation will be discussed below in the context of carcass processing and utilisation.

Table 5:15 Frequency of old breaks in long bones by taxon and period (MaxAU; MDT only; excluding fresh breaks, unfused epiphyses, newborn/foetal specimens and Evans1 material).

		Cattle		Pig		Sheep/Goat		Total	
		MaxAU	%	MaxAU	%	MaxAU	%	MaxAU	%
Neolithic	Complete	64	4	84	15	214	7	362	7
	Old Break	1499	96	466	85	3091	93	5056	93
	Total	1561		550		3305		5418	
Prepalatial	Complete	2	1	30	11	31	2	63	3
	Old Break	284	99	234	89	1627	98	2145	97
	Total	286		264		1658		2208	
Palatial	Complete	6	2	138	21	242	12	386	13
	Old Break	331	98	523	79	1790	88	2644	87
	Total	337		661		2032		3030	

	Neolithic		Prepalatial		Palatial	
Complete – Old break	χ^2	p	χ^2	p	χ^2	p
Cattle-Pig	78.042	0.000	28.492	0.000	65.929	0.000
Pig-Sheep/Goat	51.168	0.000	66.797	0.000	33.097	0.000
Cattle-Sheep/Goat	11.166	0.001	2.002	0.157	31.642	0.000

	Cattle		Pig		Sheep/Goat	
Complete – Old break	χ^2	p	χ^2	p	χ^2	p
Neolithic-Prepalatial	8.097	0.004	2.263	0.132	49.899	0.000
Neolithic-Palatial	4.184	0.041	6.290	0.012	47.558	0.000
Prepalatial- Palatial	1.426	0.232	11.488	0.001	134.329	0.000

Turning to fragment types (Table 5:16), shaft cylinders are most frequent in sheep/goats, followed by pigs and then cattle. This result will partly have been determined, however, by the rarity of complete cattle long bones which might potentially be reduced to cylinders by carnivores. Moreover, the higher frequency of sheep/goat than pig cylinders may partly reflect the tendency of long, slender tibiae and metapodials of sheep/goat to break up into shaft cylinders. Patterns of fragmentation thus differ clearly between the MDT and comparison of bone breakage between periods or areas at Knossos should, where possible, be undertaken separately for each taxon. Cattle seem to be most modified by human marrow extraction and so are probably least affected by carnivore attrition.

Despite these contrasts between the MDT, the frequencies of complete long bones and long bone cylinders change between periods in a similar fashion for pigs and sheep/goats: whole bones are least common in Prepalatial, intermediate in Neolithic and commonest in Palatial material; conversely, and consistent with the expectations of carnivore attrition, cylinders are fewest in Palatial, intermediate in Neolithic and commonest in Prepalatial material. Cattle exhibit a different pattern, with the frequencies of both whole bones and cylinders being lowest in Prepalatial, intermediate in Palatial and highest in Neolithic material.

The various lines of evidence are thus largely in agreement. The frequency of gnawing is lowest, proportion of complete bones highest, proportion of bone cylinders lowest and resemblance of sheep/goat body part representation to Brain's model poorest for the Palatial period. The Neolithic and Prepalatial exhibit greater signs of carnivore attrition on all of these indices. There are subtler distinctions between the Neolithic and the Prepalatial sub-assemblages, which are harder to explain. The frequency of gnawing is higher in the Neolithic, but the severity of gnawing (as reflected in % cylinders) is higher in the Prepalatial material, while the comparison of body part representation with Brain's model is ambiguous. Whether this contradiction reflects a difference in the accessibility of bone to dogs, in the state in which bone was initially discarded, or in subsequent trampling of material is unclear.

Table 5:16 Frequency of old break types in long bones by taxon and period (MaxAU; MDT only; excluding complete specimens, shaft splinters, fresh breaks, unfused epiphyses, newborn/foetal specimens and Evans1 material).

		Cattle		Pig		Sheep/Goat	
		MaxAU	%	MaxAU	%	MaxAU	%
Neolithic	Cylinder	73	6	60	16	677	25
	End & Shaft	1105	94	321	84	2080	75
	Total	1178		381		2757	
Prepalatial	Cylinder	5	2	39	21	373	30
	End & Shaft	216	98	144	79	851	70
	Total	221		183		1224	
Palatial	Cylinder	9	3	52	11	229	14
	End & Shaft	269	97	411	89	1393	86
	Total	277		463		1622	
		Cattle		Pig		Sheep/Goat	
Cylinder vs. End/Shaft		χ^2	p	χ^2	p	χ^2	p
Neolithic-Prepalatial		5.472	0.019	2.644	0.104	15.289	0.000
Neolithic-Palatial		3.707	0.054	3.705	0.054	67.796	0.000
Prepalatial- Palatial		0.429	0.512	11.012	0.001	111.886	0.000
		Neolithic		Prepalatial		Palatial	
Cyl vs. End/Shaft		χ^2	p	χ^2	p	χ^2	p
Cattle-Pig		33.655	0.000	37.430	0.000	14.693	0.000
Pig-Sheep/Goat		14.450	0.000	6.454	0.011	2.575	0.109
Cattle-Sheep/Goat		180.319	0.000	77.132	0.000	25.643	0.000

Table 5:17 explores severity of carnivore attrition for finer chronological divisions excluding the Evans1 material for which fragmentation data are unreliable. To ensure adequate sample sizes, the fragmentation and gnawing data for all three MDT are combined. The MN and perhaps ENII/MN Transition sub-assemblages exhibit rather low frequencies of cylinders relative to gnawing, and the reverse is evident for the OP sub-assemblage. All other bone groups consistently show low levels of gnawing with low levels of cylinders, and vice versa. The causes of the marked fluctuation in frequency and severity of gnawing during the Neolithic are explored below in section 5.4.5.2.

Table 5:17 Frequencies of gnawing and old break types by sub-phase (MaxAU; MDT only; gnawing data from Tables 5:11 and 5:13; fragmentation data based on long bones only, excluding loose epiphyses, newborn/foetal specimens, cattle and Evans1 material).

	NEOLITHIC (Evans2 only)							
	Aceramic	ENIa	ENIb	ENIc	ENII	ENII/MNTrans	MN	LN
No Gnawing	574	67	487	168	1466	370	2154	3164
	89%	80%	59%	59%	68%	78%	78%	81%
Gnawed	70	17	339	117	688	107	608	738
	11%	20%	41%	41%	32%	22%	22%	19%
End & shaft	215	28	160	47	348	161	711	731
	90%	82%	56%	43%	60%	83%	90%	81%
Cylinder	25	6	126	61	234	33	81	171
	10%	18%	44%	57%	40%	17%	10%	19%

	BRONZE AGE				
	PP:EMI/II	PP:EMIII-MMIA	OP:MMIB-MMIIA	NP:MMIIB-LMI	FP
No Gnawing	1316	1012	555	3806	559
	74%	81%	91%	92%	86%
Gnawed	465	231	54	317	92
	26%	19%	9%	8%	14%
End & shaft	583	412	210	1376	218
	66%	79%	82%	88%	83%
Cylinder	304	108	45	190	46
	34%	21%	18%	12%	17%

This analysis broken down by sub-phases confirms that the frequency of gnawing largely coincides with the frequency of cylinders, as a measure of severity of attrition. In the following analysis of spatial variation, therefore, where subdivision of the assemblages creates samples too small for analysis of anatomical representation or of long bone fragmentation patterns, frequency of gnawing (including data from Evans1) may legitimately be used as a measure of carnivore attrition. Again for reasons of sample size, the following analysis combines data from pig and sheep/goats (justified by the broad similarity between sheep/goat and pigs in the impact of carnivore attrition), but excludes cattle because of the inferred impact of human processing on cattle bones.

5.4.4.4 *Conclusion*

In the Knossos assemblage as a whole, carnivore attrition seems to have influenced fragmentation patterns to a major degree in sheep/goats and pigs, but not in cattle; the causes of fragmentation in cattle, especially, are considered further in the next chapter. Both carnivore attrition and human carcass processing evidently played a major role in bone fragmentation but the impact of trampling has not been recognised.

Prepalatial bone groups were subject to both more frequent and more intensive scavenger attrition than Palatial material. Overall, the Neolithic material resembles the Prepalatial but great differences in scavenger attrition were observed between sub-phases, which will be further explored in section 5.4.5 in relation to spatial and contextual variation.

These results have several implications for subsequent analyses.

- Caution is required, in the case of Prepalatial and ENIb-ENII bone groups, in interpreting taxonomic and elemental composition and age profiles, as smaller-bodied taxa and younger age groups are likely to have suffered losses due to scavenger attrition; conversely, the composition of the Palatial and Aceramic assemblages is more likely to reflect that of the materials originally deposited by human agency.
- The sharp contrast in attrition between the Palatial and Prepalatial assemblages implies a marked difference in depositional environment and thus, probably, in the spatial organisation of the areas excavated.
- Faunal remains from the Neolithic present a more varied picture, which is not unexpected in view of the great temporal span covered and the variety of areas sampled by Evans. The following section therefore investigates Neolithic scavenging patterns in greater detail (where the size of sub-assemblages allows), to explore the causes of apparent temporal variation and to investigate possible spatial variation.

Additionally, some clear contrasts were noted between taxa:

- The higher frequency of attrition observed on pig remains compared to sheep/goats in the Neolithic and Palatial assemblages;
- The consistently high – in all three periods – levels of fragmentation observed for cattle remains.

These patterns may result from processes preceding discard and their meaning will be further investigated in following sections.

5.4.5 Scavenger attrition: spatial differentiation

5.4.5.1 *Introduction*

For most periods, it is possible to attempt a comparison of bone groups recovered in different areas. This is necessary in order to establish whether temporal patterns emerging from the analysis are an artefact of the averaging of great spatial and contextual differences and also, ultimately, in order to shed light on use of space and refuse disposal. With these aims in mind, the following section investigates spatial variation in scavenger attrition and, in combination with other archaeological evidence (presented in detail in Chapter 3), attempts to interpret this in terms of differences in the use of space and depositional context. Analysis relies primarily on frequency of attrition, since subdivision of the assemblages both chronologically and spatially yields samples too small for useful comparison of sheep/goat anatomical representation with Brain or even, in many cases, for reliable assessment of fragmentation patterns. Previous sections, however, have shown that frequency of attrition more or less matches severity.

5.4.5.2 *Neolithic*

Comparison of bone groups from different areas of the site revealed several statistically significant differences (Table 5:18).

Table 5:18 Comparison of frequencies of gnawing in different areas within Neolithic sub-phases (data from Table 5:19 to Table 5:25).

	Aceramic		ENIa		ENIb		ENIc		ENII		MN		LN (Evans2)	
AREA	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p
Trenches X and/or ZE vs. AC	0.222	0.637	0.132	0.716	3.757	0.053	-	-	-	-	-	-	-	-
Central vs. West Court	-	-	-	-	47.297	0.000	0.865	0.352	46.842	0.000	0.012	0.912	19.130	0.000

The material of the Aceramic phase, from trenches AC and X (in the CC) and ZE (south of the CC), was uniformly subjected to limited scavenger attrition (Table 5:19). The nature of the deposits excavated provides a plausible explanation for this pattern. The small exposures in trenches ZE and X revealed parts of well-preserved architectural remains, most probably belonging to houses (see Chapter 3). It is plausible that these enclosed areas restricted access to scavengers. Moreover, once collapsed, the mud-brick building materials provided a 1-2m deep matrix (Tomkins 2001: 483) within which bones were buried and preserved. It should be noted here that macroscopic observation of one such brick from the immediately later phase (ENIa) suggests that it was formed only with earth and plant material, thus pointing against the possibility that some of the bones may derive from the disintegrated wall fabric.

Although no remains of permanent structures were found in trench AC, the types of features unearthed are compatible with rapid, possibly deliberate burial of the embedded material: some of the bones were derived from a series of pits and 'fire hollows'. In some cases complete bones in very good state of preservation were burnt a dark brown colour: it is likely that these were burnt soon after consumption by humans, making them unpalatable to scavengers. Available information suggests that these features containing animal bones were concentrated in one area of the trench, away from the reported human burials. The excavated parts of the Aceramic settlement thus appear to have been devoted to habitation activities other than refuse disposal, which may explain why bones do not exhibit taphonomic characteristics typical of material dumped and readily accessible to scavengers and the absence of significant difference between trenches X, ZE and AC (Table 5:18).

Table 5:19 Frequencies of gnawing, old breaks and old break types in Aceramic deposits (MaxAU; MDT only; gnawing data exclude loose teeth, newborn/foetal specimens; fragmentation data based on long bones only, excluding loose epiphyses, newborn/foetal specimens, and Evans1 material; data for old break types exclude cattle).

	Evans1		Evans2			
Aceramic	Trench AC		Trench X		Trench ZE	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	190	88	386	90	187	88
Gnawed	26	12	45	10	25	12
TOTAL	216		431		212	
Cylinder			15	9	10	14
End & Shaft			152	91	62	86
TOTAL			167		72	
Complete			4	2	1	1
Old Break			199	98	108	99
TOTAL			203		109	

The ENIa material discussed here comes from trenches AC and X[5]. Two separate architectural phases were identified in the former, Stratum IX (containing House E) and Stratum VIII (containing House D). Faunal remains from Stratum IX show a low frequency of attrition, close to that for the Aceramic and compatible with the presence of fairly well preserved architectural remains and domestic installations, denoting an inhabited area. The somewhat increased levels of attrition thereafter (Table 5:20) could be interpreted as follows. Architectural remains were very patchy in Stratum VIII and the deposit primarily consisted of collapsed debris and infill in which pits containing complete vessels were cut. It is possible that, after the collapse of House E in the preceding period, this remained an open area in which debris gradually accumulated, or was intentionally redeposited from a rubbish dump. Tomkins (2001: 485) draws the same conclusions

[5] Material of this period was also found in trenches Z and ZG but these deposits are not discussed here as no contextual information was available at the time of writing.

from the very worn and fragmentary state of preservation of the pottery from these levels. This interpretation is compatible with the increased scavenger activity manifested in faunal remains.

Table 5:20 Frequencies of gnawing, old breaks and old break types in ENIa deposits (see Table 5:19 for details of data used).

	Evans1				Evans2	
ENIa	Stratum IX		Stratum VIII		Trench X	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	122	86	138	77	67	80
Gnawed	19	14	40	23	17	20
TOTAL	141		178		84	
Cylinder					6	18
End & Shaft					28	82
TOTAL					34	
Complete					0	0
Old Break					40	100
TOTAL					40	

In trench X, ENIa material was derived exclusively from pits but levels of attrition were comparable to those in Stratum VIII (Table 5:20). Although better preservation might be expected here, it seems that the pits and activities in this area were not similar to those in Aceramic AC. The modest number of faunal remains relative to the size of the features (pits A and B yielded <50 specimens from approximately 8.5m^3) and the absence of evidence for rapid burial (e.g., absence of articulating elements and matching unfused ends and shafts) are compatible with the relatively high levels of scavenger attrition. They all suggest that the faunal material was incorporated in the deposits not immediately after consumption and/or processing, but after exposure for some time on the surface.

In the following three phases, material derives mainly from the Central and West Courts. As well as an overall increase in frequency of attrition, significant (ENIc) and highly significant (ENIb, ENII, LN) differences are observed between the two areas (Table 5:18), with material from the West Court being more heavily affected by scavengers.

In the ENIb, significant (Trench AC vs. X) and highly significant differences (CC vs. WC) are observed between different areas of the site (Table 5:18). Material in trench X exhibited levels of attrition similar to those of the previous phase in the same trench (Table 5:21); the deposits excavated here represent the continued infilling of the pits discussed above and similar processes of accumulation may account for the comparable state of preservation.

Trenches AC (CC) and AA/BB (WC) show higher levels of carnivore attrition (Table 5:21). Of the two distinct architectural phases identified in trench AC, Stratum VII contained two rooms of a building (House C), meaning that deposits were mostly either within the building or sealed below it. Deposits of the later phase (Stratum VI) did not contain recognisable parts of buildings, architectural remains being very patchy. Levels of attrition in both these CC strata are almost identical (30-31%). Gnawing was substantially more frequent in the WC deposits, however, where a considerably higher number of cylinders and lower number of complete bones were also recorded. The lower levels of attrition in the CC compared to WC may be attributed to different types of activity in the two areas. J.D. Evans on stratigraphic grounds considered WC to be a refuse dump at the edge of habitation (J.D. Evans 1971: 104), where it is plausible that scavengers could have roamed free. Conversely, for the CC, the presence of a building in Stratum VII and the activities implied by the facilities unearthed in Stratum VI – food preparation, cooking – denote an inhabited part of the settlement, where scavengers may have been restricted by physical barriers, or discouraged.

Table 5:21 Frequencies of gnawing, old breaks and old break types in ENIb deposits (see Table 5:19 for details of data used).

	Evans2 – West Court		Evans1 – Central Court (AC)		Evans2 – Central Court (X)	
ENIb	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	373	55	718	70	114	78
Gnawed	306	45	311	30	33	22
TOTAL	679		1029		147	
Cylinder	112	46			14	32
End & Shaft	130	54			30	68
TOTAL	242				44	
Complete	16	5			9	14
Old Break	280	95			56	86
TOTAL	296				65	

ENIc deposits were found in both the CC (trenches AC and X) and WC. Material from trench AC displays a highly significantly lower frequency of scavenger attrition than the other two (Table 5:22). Trench AC contained architectural remains, better preserved in the lower part of the deposit. Conversely, the excavator does not report any such remains from the WC and, apparently, regarded the character of the area as unchanged throughout ENI; continued use as a refuse dump at the edge of the site is certainly compatible with the evidence of a high level of carnivore attrition. Contextual information on ENIc deposits from trench X is not currently available.

Table 5:22 Frequencies of gnawing, old breaks and old break types in ENIc deposits (see Table 5:19 for details of data used).

	Evans1		Evans 2		Evans2	
ENIc	Central Court (AC)		Central Court (X)		West Court (AA/BB)	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	292	68	71	56	97	61
Gnawed	136	32	56	44	61	39
TOTAL	428		127		158	
Cylinder			27	56	34	57
End & Shaft			21	44	26	43
TOTAL			48		60	
Complete			2	7	4	6
Old Break			64	93	68	94
TOTAL			66		72	
	Trenches AC - X					
χ^2 tests	χ^2	p				
Frequency	6.569	0.010				

In ENII, the highly significant difference in frequency of gnawing between the two areas is still present and is again reflected in the percentages of cylinders, although the frequency of whole bones does not match expectations (Table 5:23). Levels of attrition are lower in the WC, however, than in earlier phases, which may be due to the appearance here for the first time of substantial architectural remains; part of the excavated area is now taken up by enclosed spaces, as opposed to open areas where refuse was dumped. On the other hand, although trench AC in the CC preserved architecture only in a fragmentary condition, the presence of various features like hearths, clay structures, pits, etc. (J.D. Evans 1964: 164) suggests that this part of the settlement remained built-up, thus limiting access by scavengers. The difference between the two areas in bone attrition may reflect contrasting proportions of open and closed spaces, but the limited availability of detailed contextual information prevents further consideration of this possibility.

Table 5:23 Frequencies of gnawing, old breaks and old break types in ENII deposits (see Table 5:19 for details of data used).

	Evans1		Evans2		Evans2	
ENII	Central Court		Central Court		West Court	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	504	78	216	81	1249	66
Gnawed	141	22	52	19	636	34
TOTAL	645		268		1885	
Cylinder			17	28	217	42
End & Shaft			43	72	305	58
TOTAL			60		522	
Complete			2	3	43	6
Old Break			65	97	615	94
TOTAL			67		658	

The MN deposits from both the CC and WC exhibit a decreased frequency of gnawing accompanied by fewer cylinders and more whole bones (Table 5:24). In the WC, on the other hand, gnawing appears to have diminished considerably. The lower incidence of gnawing is consistent with the presence of extensive well-preserved structures in both, and no significant difference was observed (Table 5:18). Frequency of attrition is slightly higher in CC Evans1 (trenches A-D and F) compared to the previous phase, but lower in trenches in the same area excavated in the second campaign. It is not possible to explain at present the difference between adjacent trenches in CC, due to the lack of contextual information for the Evans2 campaign.

Table 5:24 Frequencies of gnawing, old breaks and old break types in MN deposits (see Table 5:19 for details of data used).

	Evans1 (Stratum IIIb)		Evans2		Evans2	
MN	Central Court		Central Court		West Court	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	1231	73	751	81	1403	76
Gnawed	444	27	174	19	434	24
TOTAL	1675		925		1837	
Cylinder			31	12	50	9
End & Shaft			226	88	485	91
TOTAL			257		535	
Complete			19	7	87	13
Old Break			263	93	579	87
TOTAL			282		666	

LN material derives from adjacent trenches in the CC from both Evans1 and Evans2 and in the WC. The frequency of gnawing in Evans2 CC is highly significantly lower than in Evans1 CC and WC, thanks to large sample sizes. The frequency of gnawing is in the medium range for all three groups (Table 5:25), however, and the proportions of cylinders and whole bones in Evans2 CC and WC are almost identical. Although architecture survived only patchily in the CC, its poor preservation interpreted by the excavator as a result of later interference, structures must have existed there (J.D. Evans 1971: 113). The WC trenches, however, despite lacking substantial structures, contained remains of 'flimsy partitions', which probably defined enclosed areas out of bounds to scavengers. Thus, architectural evidence again seems to match the patterns of scavenger attrition observed in the faunal assemblage. It should be noted that a number of pottery phases is covered by the excavator's term 'LN', and so the exact temporal relationship between the various deposits compared here is unclear. More detailed contextual analysis should be possible when research currently under way (Tomkins, pers. comm.) makes more dating and stratigraphic details available.

Table 5:25 Frequencies of gnawing, old breaks and old break types in LN deposits (see Table 5:19 for details of data used).

	Evans 1 (Strata (IIIa-II)		Evans2			
LN	Central Court		Central Court		West Court	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	5529	76	2189	77	974	77
Gnawed	1756	24	449	17	289	23
TOTAL	7285		2638		1263	
Cylinder			114	20	57	17
End & Shaft			455	80	276	83
TOTAL			569		333	
Complete			62	9	32	8
Old Break			632	91	394	92
TOTAL			694		426	

In conclusion, despite the coarse levels of analysis (imposed by the lack of detailed contextual information), frequency of scavenger attrition (and severity, where samples are large enough to allow reliable conclusions) largely matches what is known of the architectural and spatial development of the site during the Neolithic. Levels of attrition are consistently low in built-up areas, while open refuse disposal areas exhibit fairly high levels of scavenger attrition.

5.4.5.3 *Bronze Age*

Overall, levels of scavenger attrition range from very high in the Prepalatial period to low or very low in the Palatial (this section does not discuss spatial differentiation in Final Palace deposits, since the only substantial bone groups were recovered in the Royal Road excavations). This contrast is also consistent between individual phases, although there are significant or highly significant differences between areas (Table 5:26).

Table 5:26 Comparison of frequency of gnawing between different areas in BA sub-phases (EH: EH93 and PEM combined; data from Table 5:27 to Table 5:32).

	EMI-II			EMIII-MMIA			Old Palace			New Palace	
AREA	χ^2	p	AREA	χ^2	p	AREA	χ^2	p	AREA	χ^2	p
RRN vs. WCH	72.696	0.000	RRS vs. EH	0.250	0.617	RR vs. EH	0.218	0.641	RR vs. RR Pit G	4.779	0.029
RRN vs. EH	12.872	0.000	RRN vs. RRS	120.421	0.000	RR vs. AQW	12.555	0.000	RR vs. RR Iv Dep	0.830	0.362
RRN vs. PW	7.308	0.007	RRN vs. EH	34.576	0.000	RR vs. RT	2.244	0.134	RR vs. HH	25.663	0.000
WCH vs. EH	0.623	0.430				RT vs. AQW vs. EH	4.560	0.102			
EH vs. PW	0.793	0.373									
WCH vs. PW	4.400	0.036									

In the Prepalatial, the greatest frequency of gnawing was observed in EMI-II deposits from RRN followed by PW. EH and WCH assemblages had suffered less, and the evidence for severity of attrition is compatible with that of frequency (Table 5:28). Differences in frequency of gnawing are highly significant between RRN, on the one hand, and WCH, EH and PW on the other (Table 5:26).

The RRN material exhibits levels of gnawing comparable to those observed on Neolithic material deposited in what are thought to represent open refuse areas at the edge of the settlement and, indeed, only a very small area of EMII deposits in RRN was thought to belong to an internal space (Hood *in prep*). Conversely, the proportions of scavenger modified specimens in WCH and EH, where extensive architectural remains were uncovered, are more similar to those observed in the Neolithic inhabited areas. The limited exposure of EMII deposits in this area, however, combined with the small size of the faunal samples, precludes detailed contextual analysis.

Slightly more detailed analysis is possible for WCH as the exposures were more extensive and therefore the stratigraphy and architectural history of the building more amenable to interpretation. Faunal remains derive from three successive phases: from a cutting/pit below the house and in-filled prior to its construction (Phase 2); from within the structure and from adjacent yard deposits, while it was in use (Phase 3); and from the fill used to level it (Phase 4). The deposits of all three phases were formed during the same ceramic phase (EMIIA), as concluded from ceramic and stratigraphic analysis; in-filling in Phases 2 and 4 appears to have been deliberate and not a result of gradual accumulation of debris (Wilson 1985).

The frequency of gnawing is compatible with the history of the building as described by Wilson. The lowest frequency of attrition is observed in the Phase 3 occupation material, recalling the Neolithic pattern of reduced scavenger attrition in deposits associated with buildings in use. On the other hand, the frequency of gnawing is higher in the Phase 2 (significantly so) and Phase 4 fills, matching levels observed in Neolithic building fills. Although the origin of these fills is unknown, taphonomic evidence suggests that they were not collected from highly exposed rubbish dumps. Overall, severity of attrition is comparable between the three phases and no significant differences were observed (Table 5:27).

Table 5:27 Frequencies of gnawing, old breaks and old break types in different phases of WCH (see Table 5:19 for details of data used).

WCH	Phase 2		Phase 3		Phase 4	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	278	81	131	89	200	84
Gnawed	67	19	16	11	39	16
TOTAL	345		147		239	
End & Shaft	122	71	71	71	163	71
Cylinder	50	29	29	29	66	29
TOTAL	172		100		229	
Complete	6	3	6	4	4	1
Old Break	219	97	130	96	287	99
TOTAL	225		136		291	

WCH	Frequency (gnawed-ungnawed)		Complete vs. Fragmented		Cylinders vs. End specimens	
	χ^2	p	χ^2	p	χ^2	p
Phase 2&3	5.356	0.021	0.803	0.370	0.000	0.990
Phase 3&4	2.199	0.138	3.738	0.053	0.001	0.974
Phase 2&4	0.915	0.339	1.115	0.291	0.004	0.957

The faunal remains from PW are similar in frequency and severity of attrition to those described above from WCH fills. Again stratigraphic and pottery evidence suggests that this fill was dumped into the EMI well after it went out of use in a single event, but scavenger modification (Table 5:28) implies that the faunal assemblage was deposited in the well after exposure for some time rather than immediately after processing and/or consumption.

The faunal material from EH of the Prepalatial period (EMIIB-III) is too scanty for reliable comparison of different deposits (Table 5:28 and Table 5:29). All that can be said is that levels of attrition are comparable to those observed for deposits of similar character (i.e. fills of rooms, wall foundation trenches and pits) and contrast with those for EMIII material from RRN. This latter material, like the earlier EMIIB bone from the same area, exhibits the highest levels of scavenger attrition, expected for material discarded in open dumps (Table 5:29).

Table 5:28 Frequencies of gnawing, old breaks and old break types in EMI-IIB deposits (see Table 5:19 for details of data used).

EMI-IIB	West Court House		EH		PW		RRN	
	MaxAU	%	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	612	83	99	80	104	76	504	64
Gnawed	122	17	24	20	33	24	283	36
TOTAL	734		123		137		787	
Cylinder	145	29	10	20	8	24	138	46
End & Shaft	356	71	38	80	26	76	162	54
TOTAL	501		48		34		300	
Complete	16	2	0	0	1	2	7	1
Old Break	636	98	58	100	50	98	507	99
TOTAL	652		58		51		514	

In conclusion, bone groups of the EMI-III periods were variably affected by scavengers, depending on the area where they were deposited. Material from built up areas (WCH, EH) was exposed for shorter periods of time and/or was less accessible to scavengers. Severely affected bone groups in RRN, on the other hand, probably derive from material discarded in the open and exposed over longer periods of time before burial. Fills from levelled buildings exhibit levels of attrition similar to those observed on material from built-up areas, possibly implying the use of abandoned buildings as relatively inaccessible rubbish dumps. Moderate attrition of bone from the PW, implying some prior exposure above ground, is perhaps slightly surprising given ceramic and stratigraphic evidence that this deposit represents a single event.

Finally, faunal remains from the MMIA period derive in their majority from a 'fill' (Cadogan et al. 1993: 25) or 'large rubbish deposit' (Momigliano 1991: 152), excavated below floors in trench F of area RRS. Meaningful comparison with other deposits of this date is not possible due to the small size of the latter, but the following observations can be made for the rubbish deposit in trench F. The frequency and severity of attrition are towards the lower end of the spectrum, implying limited scavenger modification (Table 5:29), comparable with similar fill deposits of earlier date discussed above.

Table 5:29 Frequencies of gnawing, old breaks and old break types in EMIII-MMIA deposits (see Table 5:19 for details of data used).

EMIII-MMIA	EH93 & PEM		RRN		RRS (MMIA)	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	74	88	83	50	854	86
Gnawed	10	12	84	50	137	14
TOTAL	84		167		991	
Cylinder	7	21	27	43	74	18
End & Shaft	26	79	36	57	350	82
TOTAL	33		63		424	
Complete	2	5	4	3	29	6
Old Break	39	95	119	97	447	94
TOTAL	41		123		476	

Some RR bone groups from Palatial period deposits firmly fall in the category of faunal remains minimally affected by scavenger attrition. These can be contrasted with AQW, for the Old Palace period, and HH and – with some reservation due to small sample size – RT, for the New Palace period, which exhibit levels close to those of Prepalatial fills in structures and pits (Table 5:30). Presently, detailed discussion of these deposits is precluded by the absence of published information on the architecture and stratigraphy. It is known, however, that LMI deposits in RRN were associated with a large building and that some of the bone groups derive from pits in the area. One of these, pit G, contained a fairly large group of bones and exhibited the lowest recorded frequency

of attrition of all the deposits examined. The low levels of scavenger attrition and other evidence, discussed in the following chapter, strongly suggest this pit contained deliberately buried primary deposits[6].

Of the smaller deposits, AQW and HH are of further interest, as they are comparable to material from earlier periods and they were excavated at some distance from the main deposit discussed above (RR). AQW is another example of a fill dumped in an abandoned well, with a similar frequency of gnawing to PW (the sample is too small for meaningful comparison of severity). HH deposits of the Neopalatial period exhibit a higher frequency of gnawing than RR, more akin to that observed for built-up areas of the Prepalatial and Neolithic periods (Table 5:31).

As with earlier discussion of Neolithic and Prepalatial material, this attempt at spatial analysis is hampered by a lack of relevant stratigraphic and contextual information. Overall, however, where adequate information is available, the architectural and stratigraphic evidence for use of space matches that of the faunal remains. The heavily built-up areas and closed features (mainly in RR) yielded bones on which scavengers had inflicted minimal damage, whereas material from areas at some distance from the main palatial complex (AQW, RT, HH) exhibited higher levels of attrition, implying that faunal remains were more accessible to scavengers. This contrast is important both as a factor complicating analysis of these groups of material in terms of pre-depositional human behaviour and also as evidence for the spatial organisation of human behaviour at Knossos.

[6] It is likely that this is the case with other pits in the area, but adequate stratigraphic information was not available at the time of this study to ascertain this.

Table 5:30 Frequencies of gnawing, old breaks and old break types in Old Palace deposits (see Table 5:19 for details of data used).

Old Palace	EH93		RT		AQW		RR		HH	
	MaxAU	%	MaxAU	%	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	81	92	51	88	64	81	345	93	14	93
Gnawed	7	8	7	12	15	19	24	7	1	7
TOTAL	88		58		79		369		15	
Cylinder	8	20	4	15	11	38	22	14	0	0
End & Shaft	32	80	23	85	18	62	134	86	3	100
TOTAL	40		27		29		156		3	
Complete	7	13	0	0	5	12	48	23	0	0
Old Break	45	87	29	100	36	88	163	77	3	100
TOTAL	52		29		41		211		3	

Table 5:31 Frequencies of gnawing, old breaks and old break types in Neopalatial deposits (see Table 5:19 for details of data used).

New Palace	RT		RR		HH	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	30	83	3632	93	147	82
Gnawed	6	17	279	7	32	18
TOTAL	36		3911		179	
Cylinder	1	7	178	12	11	11
End & Shaft	14	93	1273	88	93	89
TOTAL	15		1451		104	
Complete	0	0	297	15	6	5
Old Break	18	100	1627	85	111	95
TOTAL	18		1924		117	

Table 5:32 Frequencies of gnawing, old breaks and old break types in RR Neopalatial deposits (see Table 5:19 for details of data used).

New Palace: RR	RR Pit G		RR 'Ivory Deposit'		RR other	
	MaxAU	%	MaxAU	%	MaxAU	%
Non-gnawed	394	96	619	92	2619	93
Gnawed	18	4	56	8	205	7
TOTAL	412		675		2824	
Cylinder	16	9	28	10	134	13
End & Shaft	156	91	244	90	873	87
TOTAL	172		272		1007	
Complete	34	14	43	13	220	16
Old Break	202	86	298	87	1127	84
TOTAL	236		341		1347	

5.5 Conclusion

Taphonomic processes have contributed to the present composition of the Knossian material in several ways. First, work by previous researchers has affected the composition of the Evans1 material, as a result of transport damage and subsequent selective discard of non-identifiable specimens. Fragmentation patterns in this sub-assemblage to a great extent reflect these processes and so cannot be used for other types of analysis; the same processes are also likely to have transformed anatomical and taxonomic composition.

Secondly, variable methods of recovery (partial sieving of early phases of the Neolithic and a 'special' BA deposit; hand collection in the trench for all other sub-assemblages) have affected the anatomical and, to some extent, the taxonomic composition of all the assemblages. Differences between sub-assemblages recovered in different ways, although not dramatic, are nevertheless pronounced for phalanges of pigs and sheep/goats; variation in abundance of small elements must thus be interpreted with great caution.

Thirdly, scavenger attrition has affected the anatomical and, probably, taxonomic composition of the assemblages and has also influenced fragmentation patterns, especially of pigs and sheep/goats. Palatial bone groups are the least affected by differential post-excavation damage, recovery and scavenger attrition and are therefore most likely to be representative of the material originally discarded/deposited and by extension more closely reflect human behaviour. Prepalatial assemblages, although not modified by the types of excavation and post-excavation processes relevant to the Neolithic material, were affected by intensive scavenger attrition. Neolithic assemblages present the most complex picture, as some have been affected by all of the above filters, and others not. The impact of scavenger attrition thus varies significantly in time and space, more or less in accordance with changes in the spatial organisation of human behaviour (notably the opposition between enclosed habitation space and apparently open midden areas). Such contextual variation must be considered in subsequent analysis and interpretation of assemblage composition as evidence for pre-depositional human behaviour. There are also clear differences between the three MDT in exposure to attrition and other agents of bone fragmentation. These may reflect differences in methods or contexts of carcass processing and are further considered in the next chapter.

6 CARCASS PROCESSING, CONSUMPTION AND DISCARD PRACTICES

6.1 Introduction

Having in the previous chapter investigated depositional and post-depositional processes, analysis proceeds here to explore human agency as revealed by the assemblages under study. Anatomical representation, butchery marks and fragmentation patterns are analysed in order to shed light on practices related to refuse disposal, carcass processing and uses of primary products (meat, bones, horn). These analyses are concentrated mainly on MDT for the reasons set out previously. Other taxa are discussed separately at the end, using a combination of the above, as their rarity renders any one type of evidence (anatomical representation, fragmentation, butchery, working) insufficient for shedding light on their possible exploitation (Table 6:1).

6.2 Anatomical representation

For the purpose of this analysis, bone groups were tabulated by sub-phase and area for each MDT. These divisions were suggested by the results of previous analyses, where it has been shown that the taxonomic and anatomical composition of the different sub-assemblages have variously been affected by their treatment by previous researchers, partial recovery and scavenger attrition. Bar charts show anatomical representation for each MDT starting at the head (black), followed by fore limb (grey) and finally hind limb (white); second and third phalanges are omitted, as they have been shown to have suffered heavy losses due to recovery methods, while numbers of first phalanges were divided by two to correct for variable frequency in the skeleton. The trunk is not considered, as neither ribs nor vertebrae were recorded (see Chapter 4). It is also important in the following analysis to consider the sample size of the assemblages available for each sub-phase: in several instances samples are below 400 (cf. van der Veen and Fieller 1982), which means that apparent under- or over-representations need to be interpreted cautiously. Analysis assumes that if animals were slaughtered and butchered on site and no other filters had affected the assemblage, roughly equal numbers of all body parts (corrected for variable frequency in a complete skeleton) would be expected to be recovered.

The analysis yields the following results. First, in all sub-phases and areas, all parts of the carcass of MDT are present. Even when not all anatomical zones are present (often the case in small samples, where cattle and pigs are poorly represented), elements from all parts of the

skeleton, i.e. front and hind limbs, feet and head, were represented[1]. This implies that in all periods animals were slaughtered and their carcasses processed within the areas excavated (Figures 6:1 to 6:13). Further implications of this observation in terms of human behaviour are discussed at the end of this chapter.

As a first step towards understanding frequency of anatomical zones, it is important to interpret occasional absence or uneven representation in the light of processes identified in the previous chapter: handling by previous analysts, recovery methods and scavenger attrition. Marked over-representation of mandibles in Evans1 material is compatible with other evidence for transport damage and subsequent selective retention by previous analysts (Figure 6:3 b, c, f; Figure 6:4 c, f; Figure 6:5 c; Figure 6:7 a, c; Figure 6:8 a, c, d, f) and, in LN deposits from Evans2, is probably a result of sorting by Winder (Figure 6:8 g, h, i, l). In other instances, where the effect is not as dramatic, it is most likely a result of high levels of scavenger attrition identified in the previous chapter for these particular phases, i.e. ENIc, MN and Prepalatial (Figure 6:4 f; Figure 6:7 f; Figure 6:9 f).

Under-representation of small ankle and foot bones of sheep/goat and pigs due to partial recovery is evident in all phases and most dramatically so for non-sieved assemblages (Figure 6:1 c to Figure 6:8 c; Figures 6:2 f, 3 f and 8f; sheep/goat in Figure 6:9 to Figure 6:13 Figure 6:9 to Figure 6:13 excluding Figure 6:12 f). The effect of complete sieving is apparent in Figure 6:1 f, i and Figure 6:12 f. These bone groups – Stratum X and the Ivory Deposit - are particularly suitable for observing recovery bias as they are some of the least scavenger ravaged in the whole assemblage (thus removing another potential filter).

Scavenger attrition adequately explains other instances of over- and under-represented anatomical zones: the common over-representation of the robust distal humerus and/or distal tibia in sheep/goats and the under-representation of the vulnerable proximal femur in the same taxa (Figure 6:1 c, i; Figure 6:3 c,f,l; Figure 6:4 c, f, i; Figure 6:5 c, i; Figure 6:7 c, f; Figure 6:8 c, f, i, l; Figure 6:9 f, i; Figure 6:10 c, f, i; Figure 6:11 l; Figure 6:12 c). Similarly, no differences in spatial distribution of anatomical zones which are not explainable by different levels of scavenger attrition are observed between the two main areas of exploration in the Neolithic, the Central and West Court.

A number of other discrepancies are not plausibly attributable to the above processes. In the Neolithic, sheep/goat scapula and (less often) pelvis are inflated in some sub-phases, exceeding

[1] Head – mandibles, loose mandibular teeth, horncore, antler; fore limb – scapula, humerus, radius, ulna; hind limb – pelvis, femur, tibia, astragalus, calcaneum; feet – metacarpals, metatarsals, phalanges.

or equalling in number other more robust parts of the skeleton (distal humerus and tibia), a pattern unexpected for these carnivore ravaged assemblages (Figure 6:2 c, i; Figure 6:3 c, f, i; Figure 6:4 c; Figure 6:5 c, i; Figure 6:7 c, f, i; Figure 6:8 c, f, i, l). Numbers of cattle first phalanx are also inflated compared to other body parts in ENIb, ENII, ENII-MN Transition, MN, LN and (Figure 6:3 a, d, g, j; Figure 6:5 a, g; Figure 6:6 a, d; Figure 6:7 a, d; Figure 6:8 a, d, g, j; Figure 6:12 g), while there is an example of over-representation of cattle astragali in Stratum V (Figure 6:4). The absence or rarity of cattle horncores combined with under-representation of cattle mandibles in Old (Figure 6:11)) and New Palace (Figure 6:12) contexts is of note. In the closed LMIA deposit from Pit G (Figure 6:12 a, c), meaty parts of the skeleton of cattle and sheep/goats are preponderant and extremities under-represented. These discrepancies are explored below in the light of butchery marks and fragmentation patterns. Differences between areas are difficult to interpret, for two main reasons. First, assemblages are rarely large enough to provide reliable samples and, secondly, for those that are, the possibility that differences result from post-depositional filters (most often scavenger attrition) cannot be ruled out.

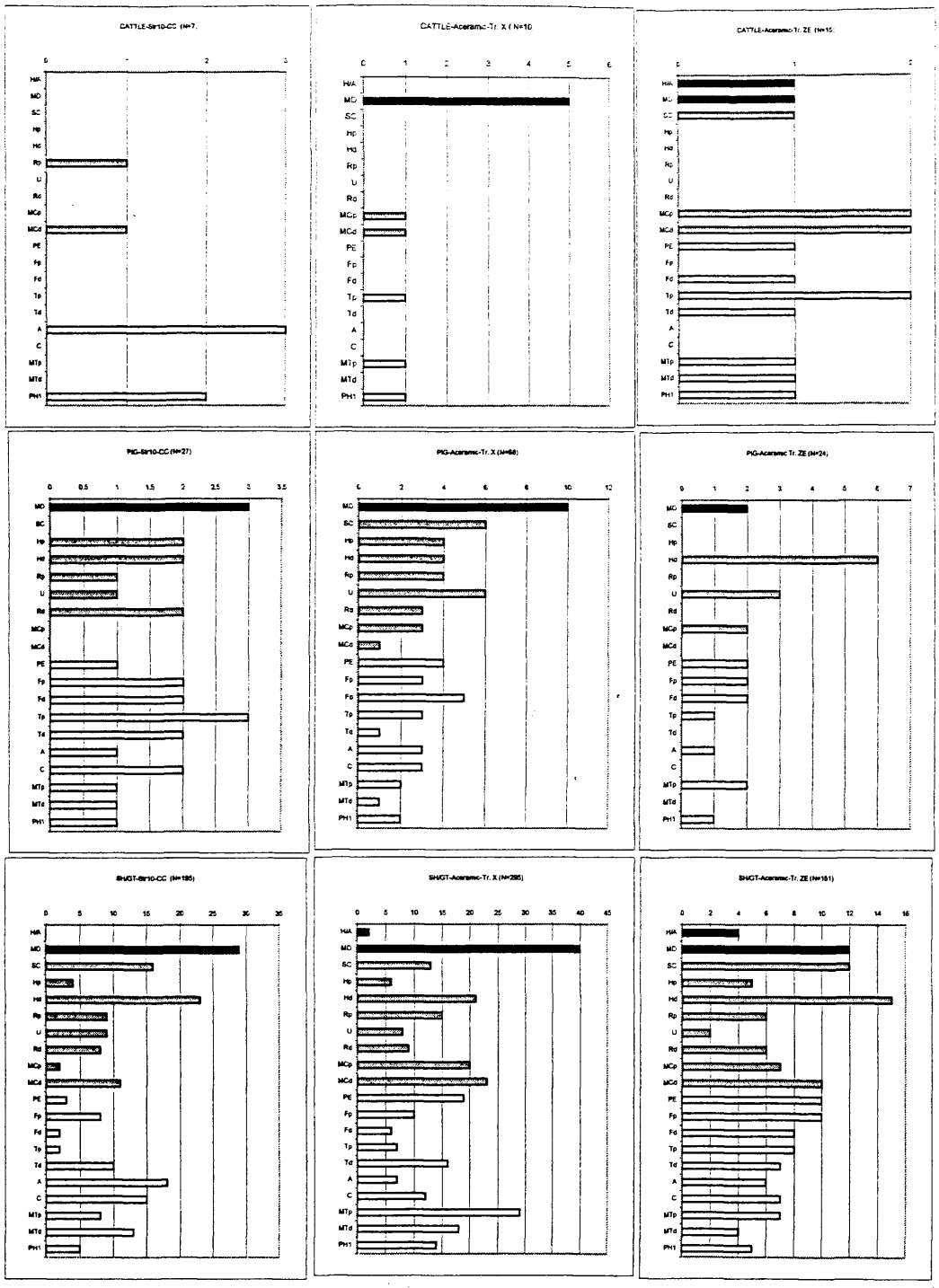


Figure 6:1 Anatomical representation of MDT in the Aceramic by area (MinAU; first phalanx counts divided by two).

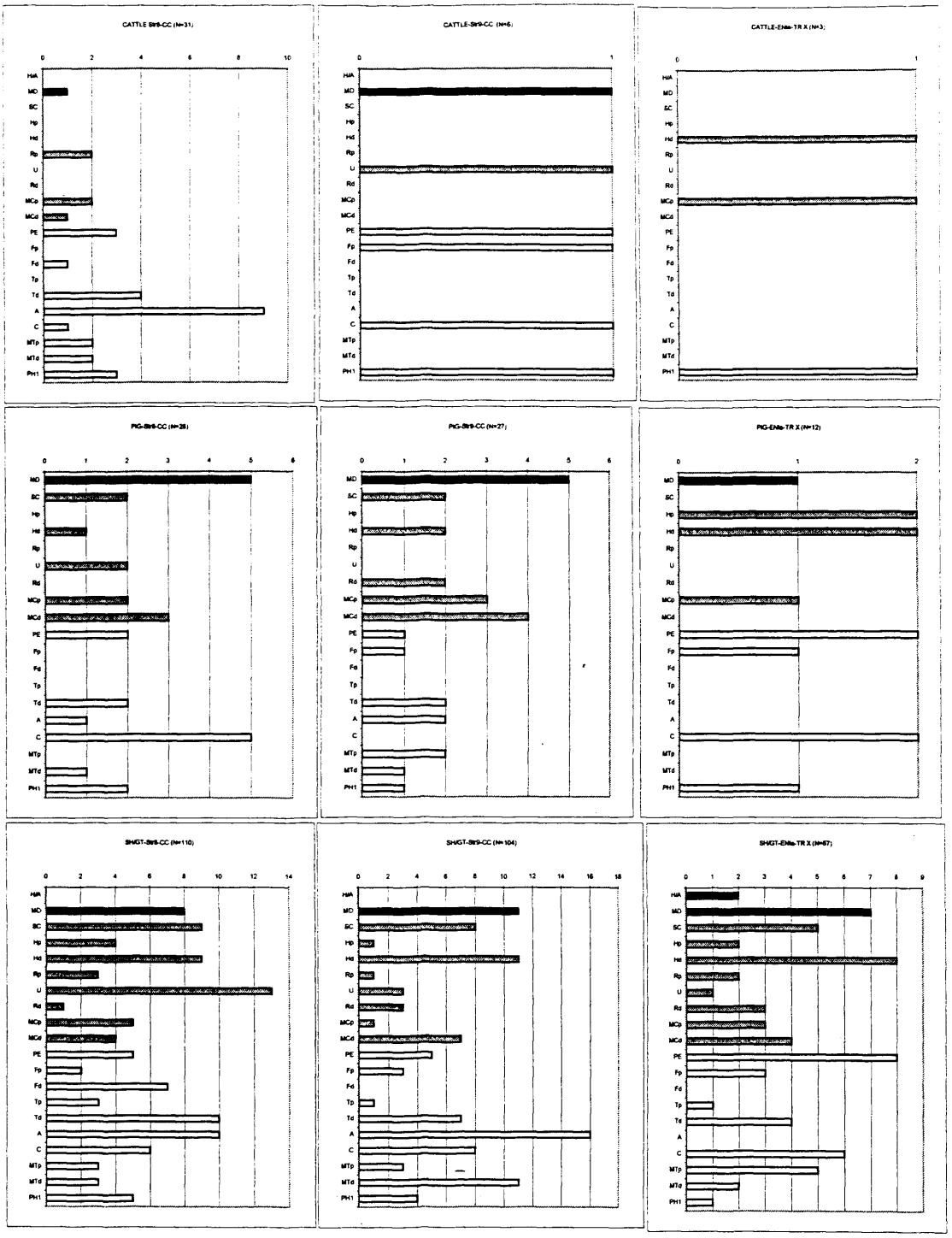


Figure 6:2 Anatomical representation of MDT in ENIa by area (MinAU; first phalanx counts divided by two).

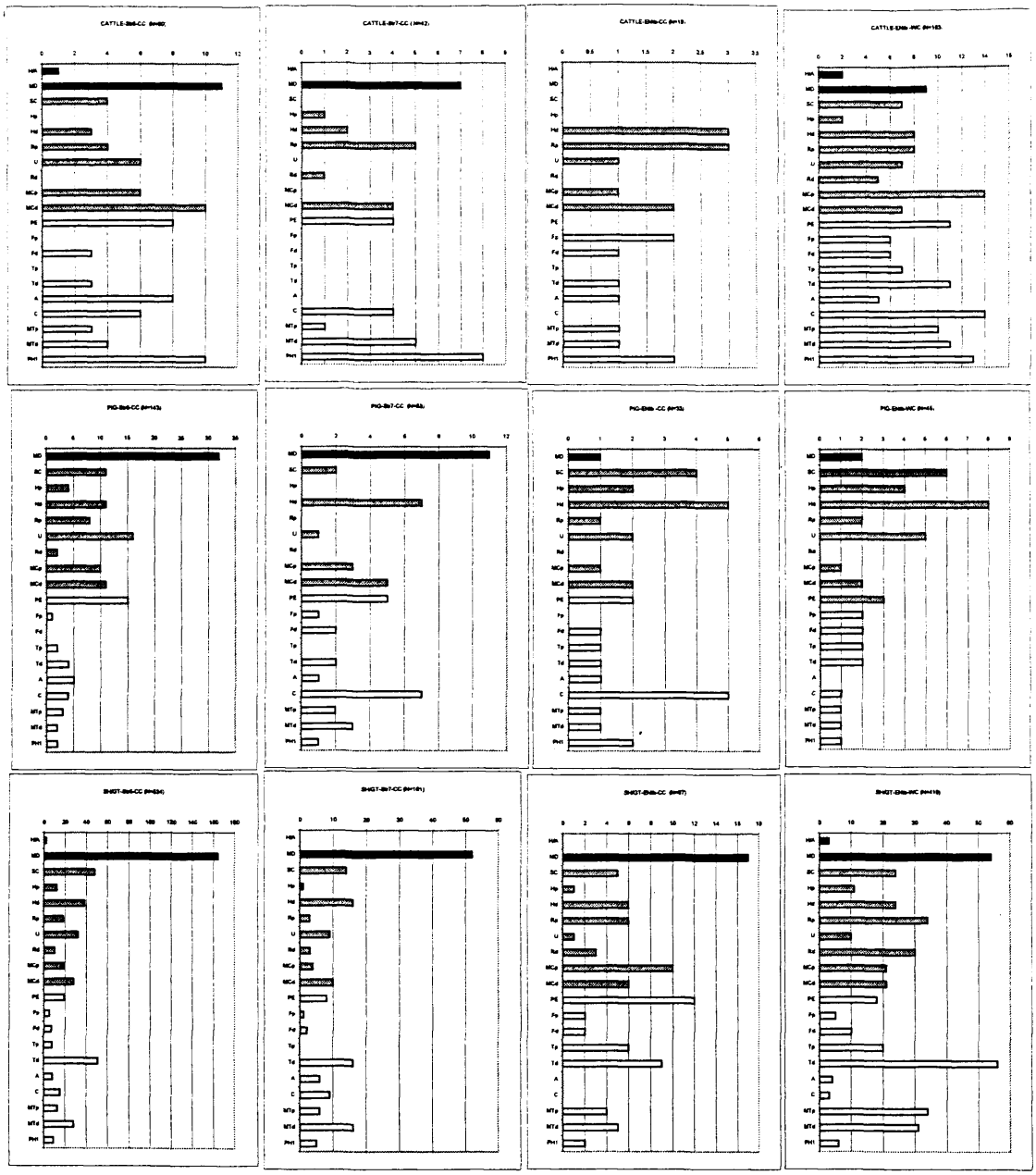


Figure 6:3 Anatomical representation of MDT in ENIb by area (MinAU; first phalanx counts divided by two).

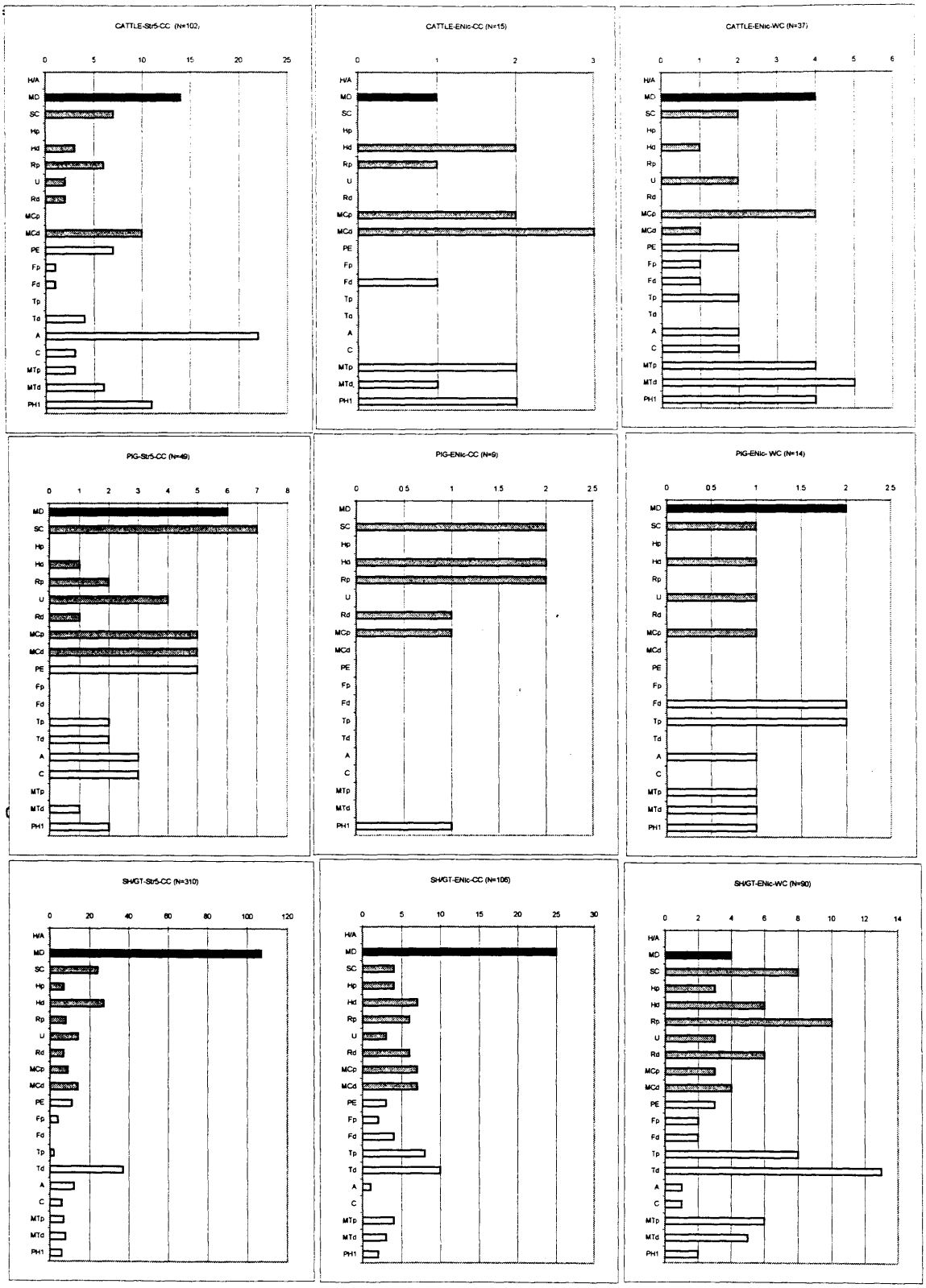


Figure 6:4 Anatomical representation of MDT in ENIc by area (MinAU; first phalanx counts divided by two).

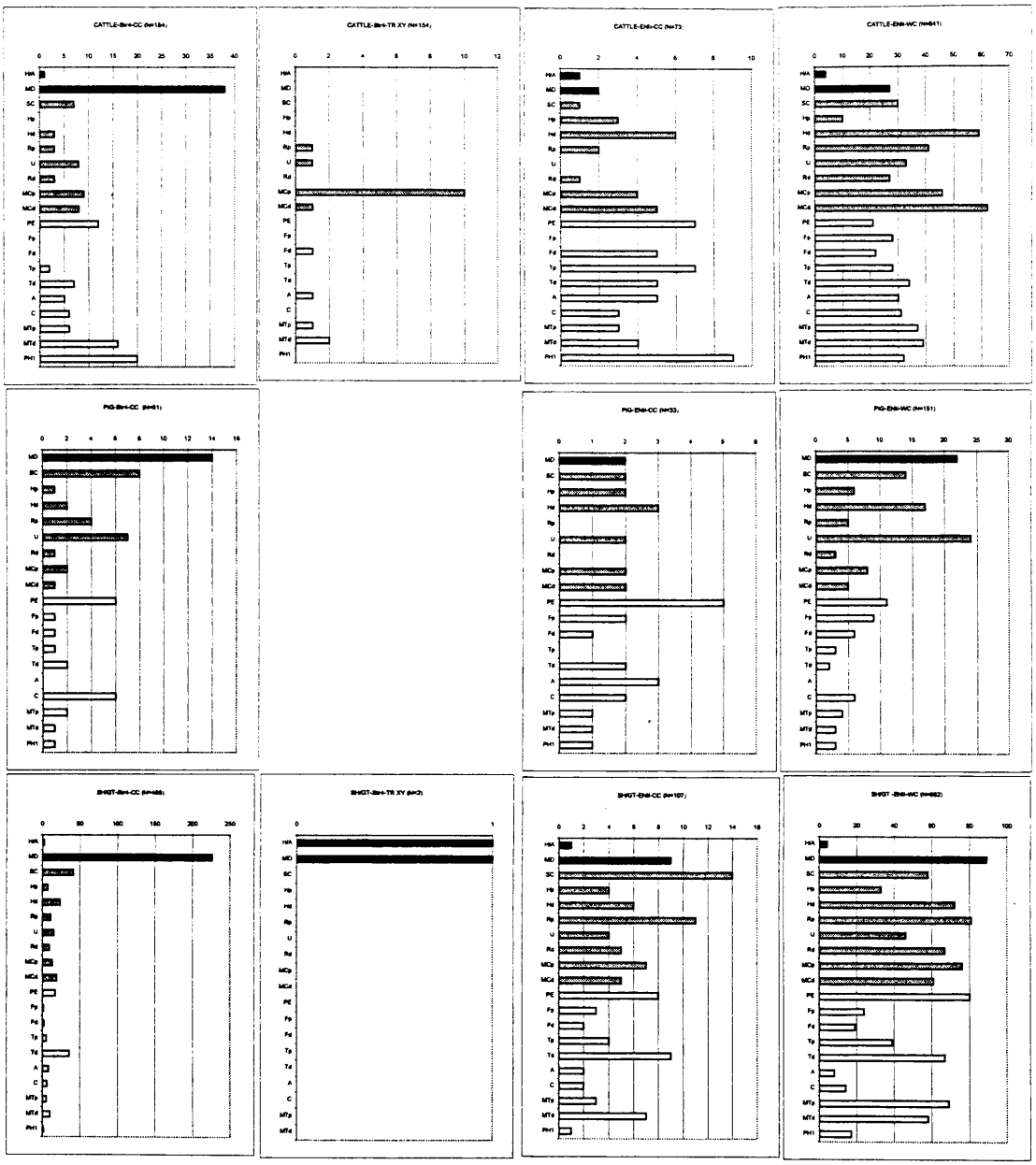


Figure 6:5 Anatomical representation of MDT in ENII by area (MinAU; first phalanx counts divided by two).

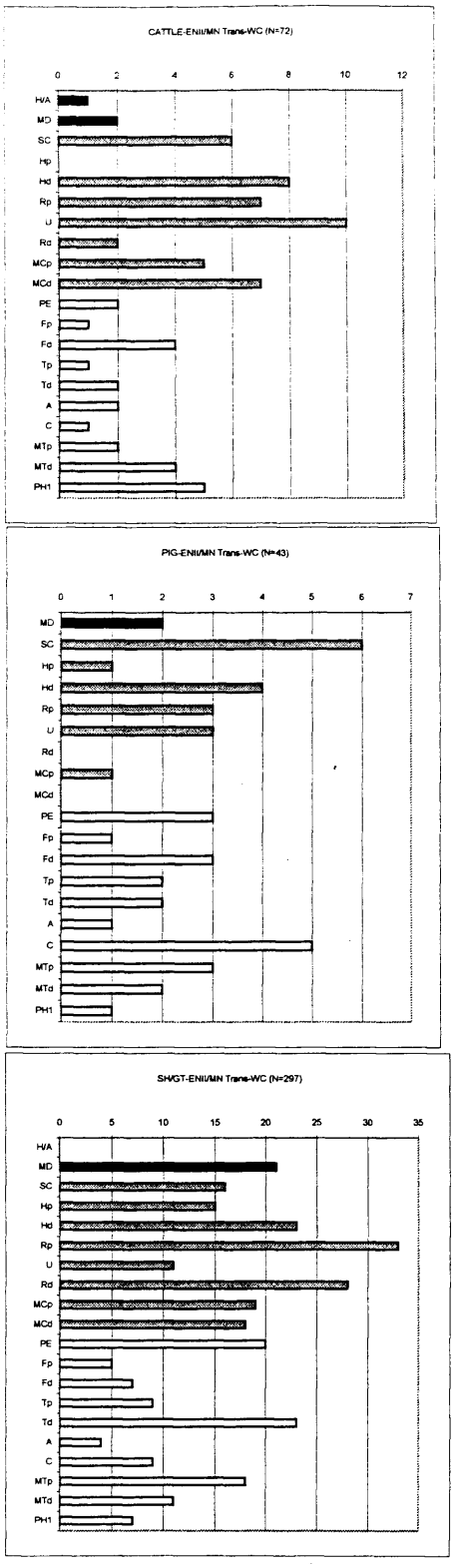


Figure 6:6 Anatomical representation of MDT in ENII-MN Trans. by area (MinAU; first phalanx counts divided by two).

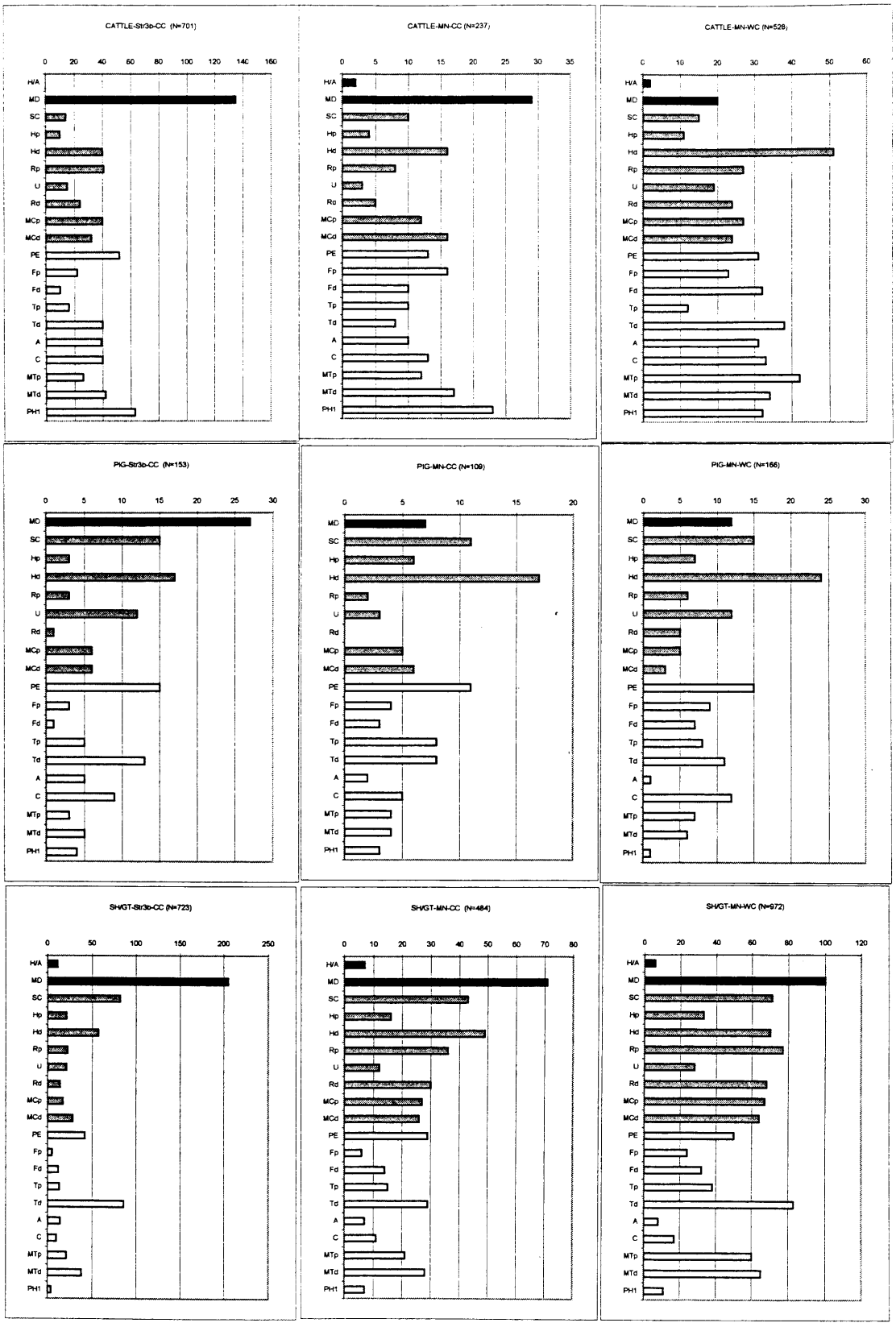


Figure 6:7 Anatomical representation of MDT in MN by area (MinAU; first phalanx counts divided by two).

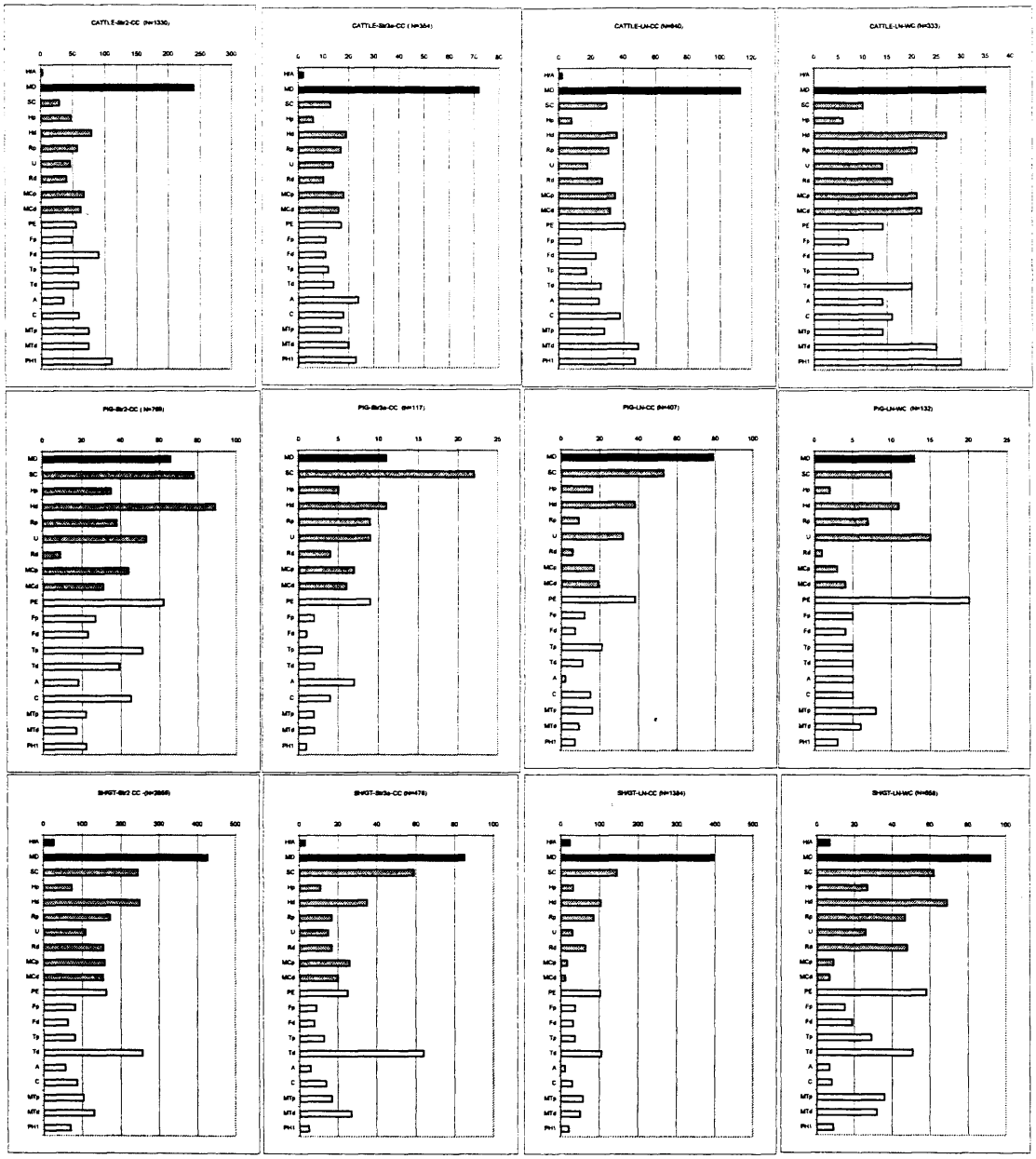


Figure 6:8 Anatomical representation of MDT in LN by area (MinAU; first phalanx counts divided by two).

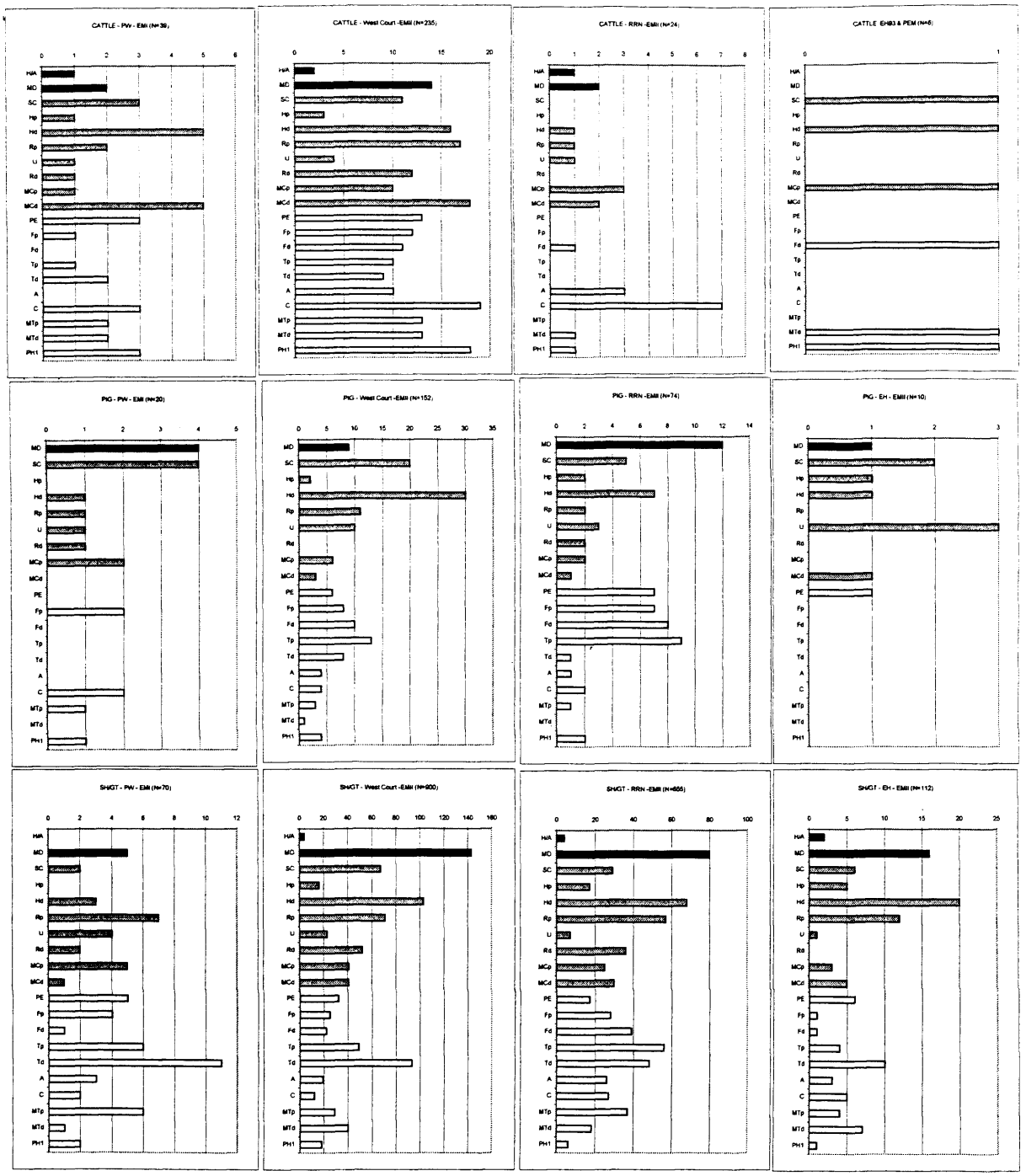


Figure 6:9 Anatomical representation of MDT in EMI-II by area (MinAU; first phalanx counts divided by two).

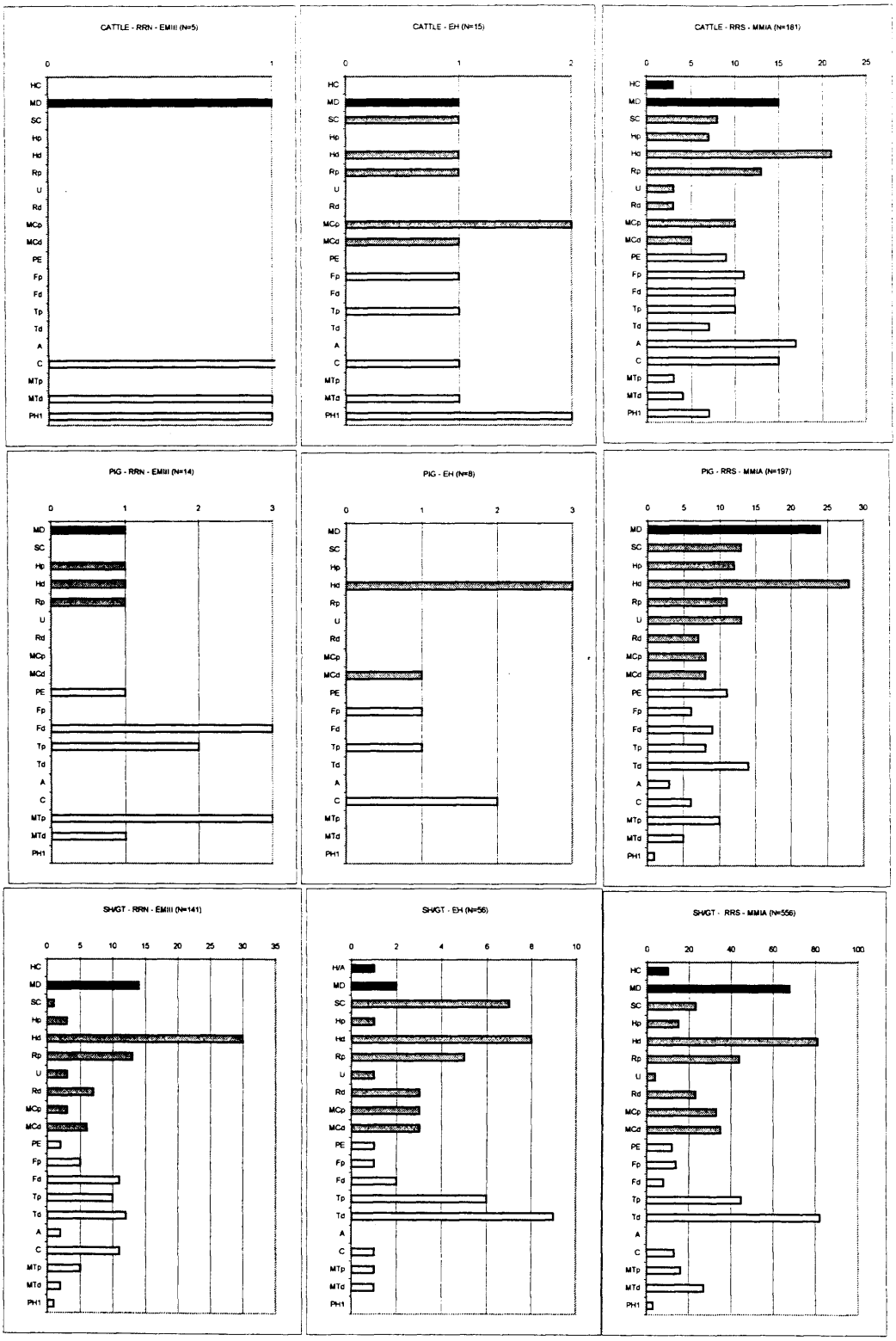


Figure 6:10 Anatomical representation of MDT in EMIII-MMIA by area (MinAU; first phalanx counts divided by two).

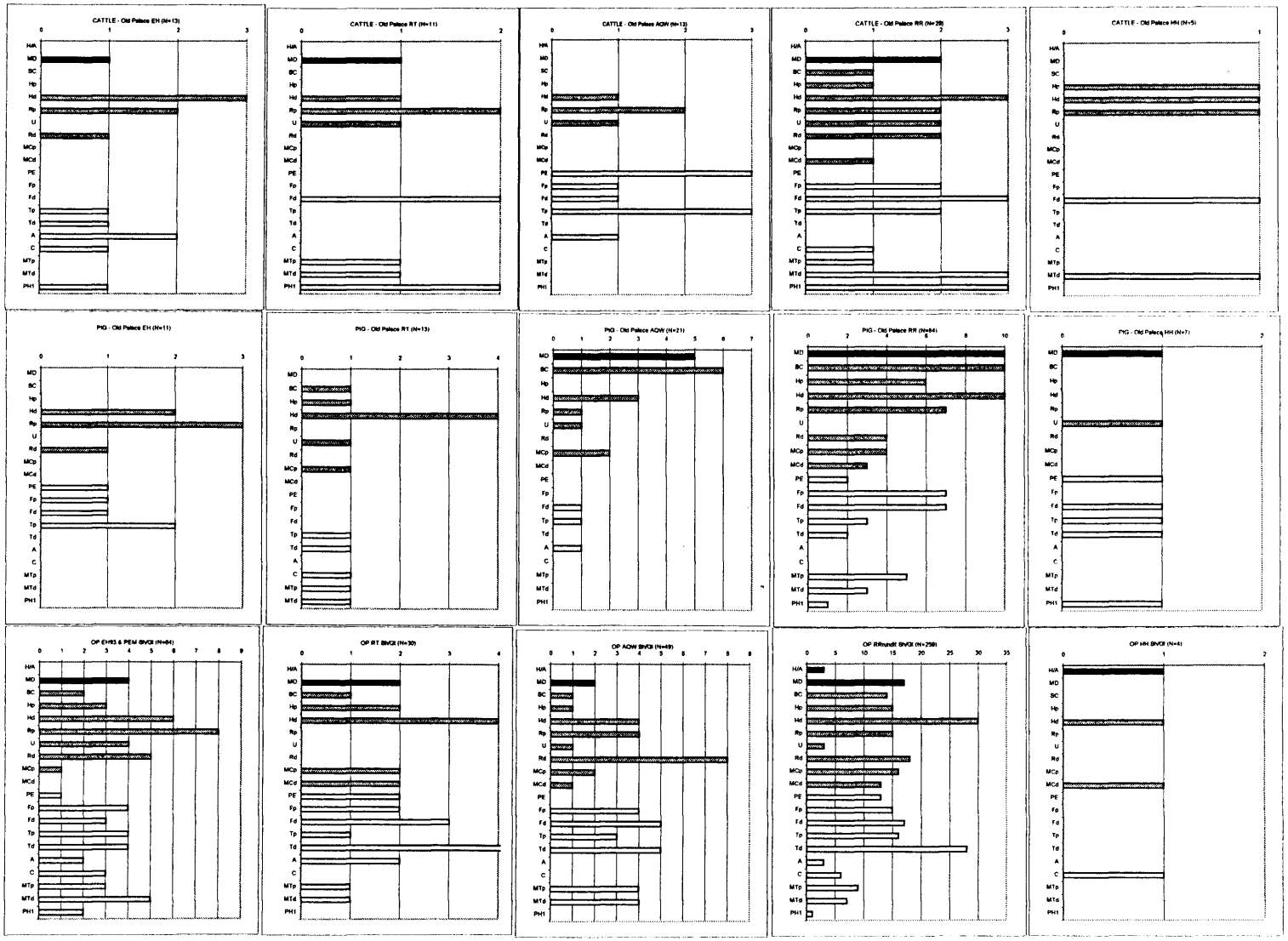


Figure 6:11 Anatomical representation of MDT in the OP by area (MinAU; first phalanx counts divided by two)

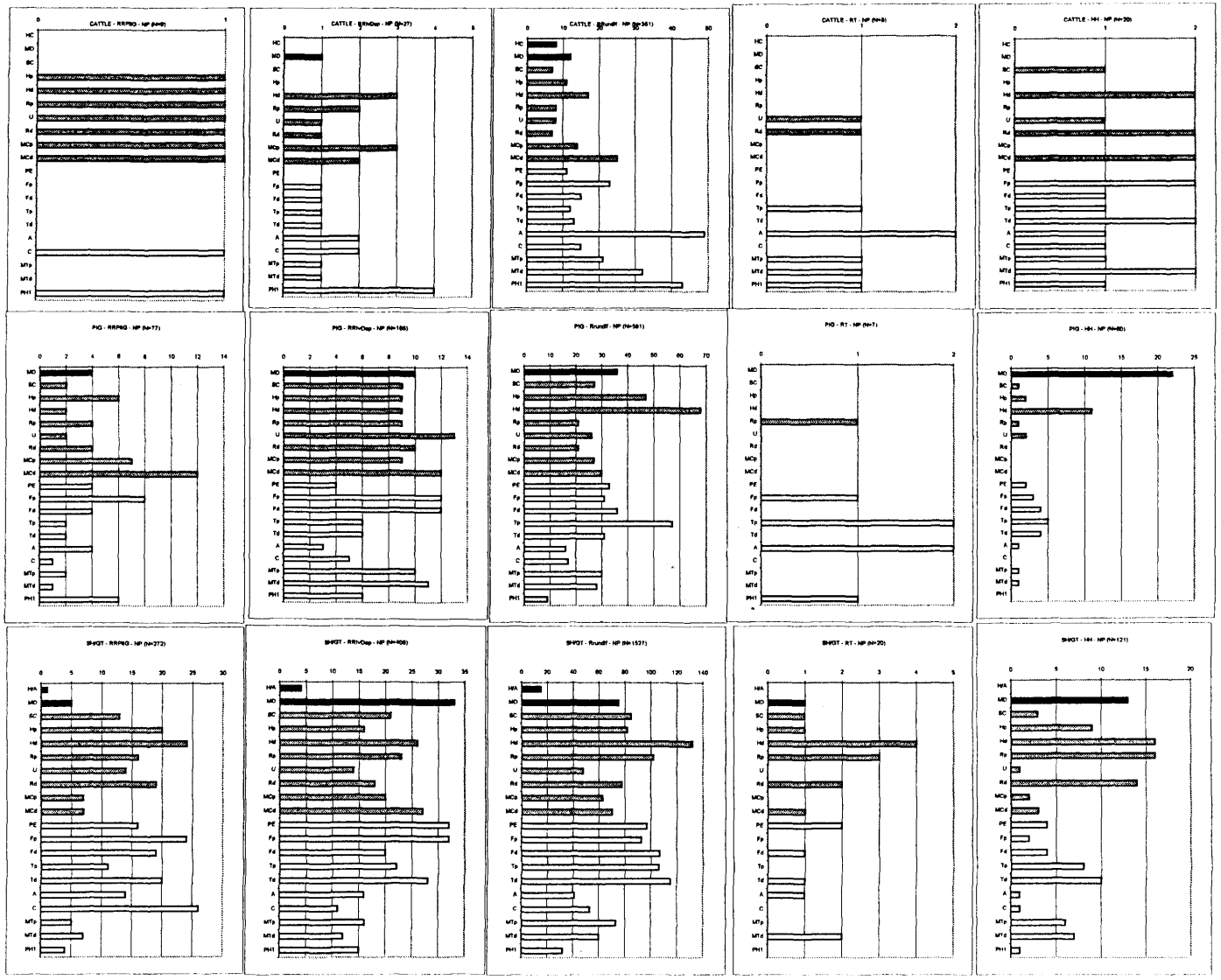


Figure 6:12 Anatomical representation of MDT in the NP by area (MinAU; first phalanx counts divided by two)

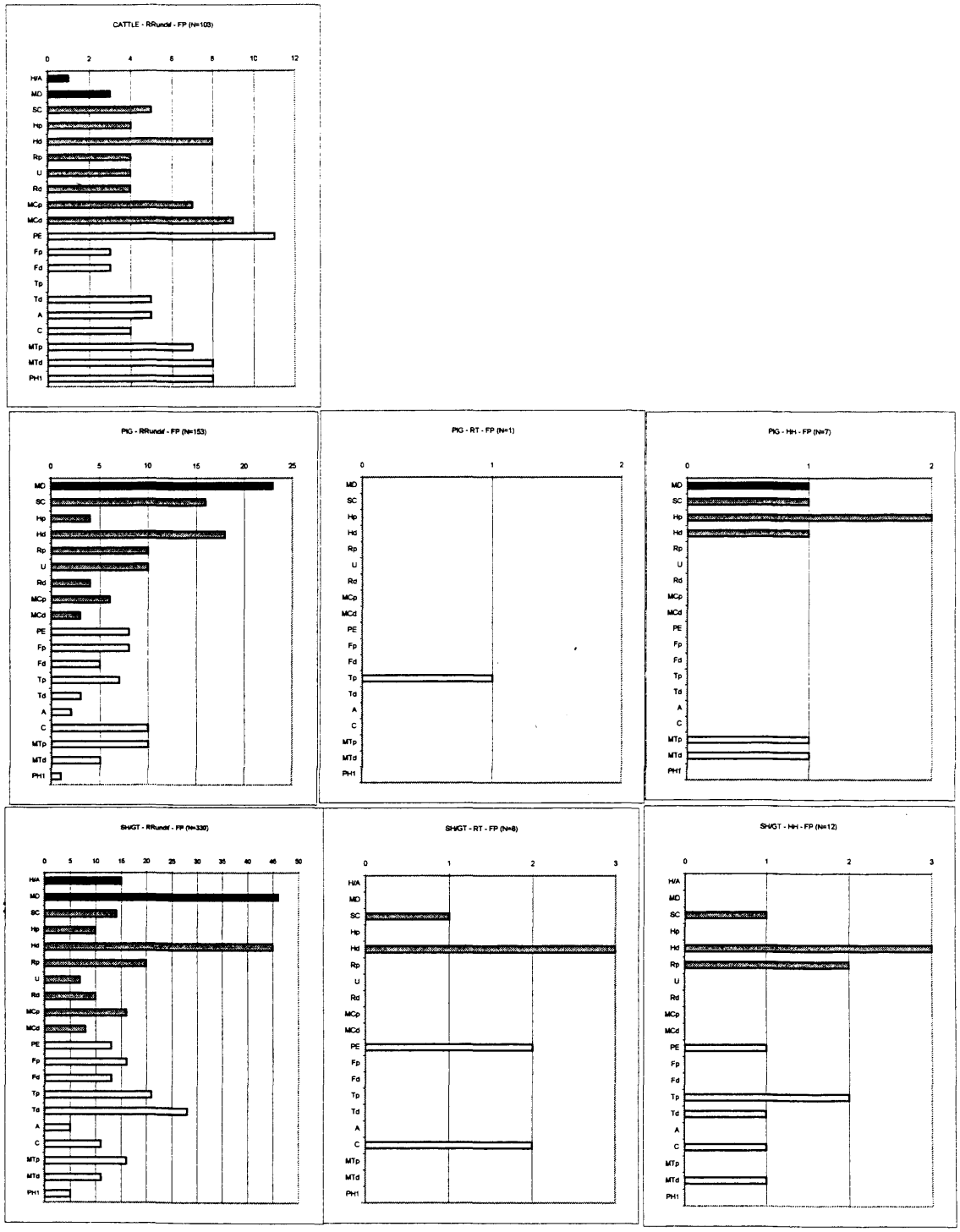


Figure 6:13 Anatomical representation of MDT in the FP by area (MinAU; first phalanx counts divided by two).

6.3 Butchery methods

Having established that all stages in the sequence of carcass processing of MDT are represented at the site based on body part representation, this section looks into *methods* of carcass processing and exploitation, using tool marks on bones. These are categorised using two sets of criteria: morphology – reflecting the types of tools used; and placement on the skeleton – reflecting methods and choices in the intensity of carcass processing and consumption (following Binford 1981). Interpretation is aided, when possible, by our understanding of contemporary technology (i.e. of tool types known archaeologically). Results are assessed in the light of conclusions drawn in Chapter 5 concerning treatment by other specialists, recovery methods and scavenger attrition. Detailed analysis is limited to MDT, as only they are present in statistically meaningful quantities, and excludes foetal and neonatal specimens, on which butchery marks were not observed, thus leaving open the possibility that these represent natural deaths rather than animals butchered to be consumed.

The aim of the section is to shed light on butchery practices, as these most probably reflect organisation of processing and consumption of primary animal products and also technological change in butchery tools. Other developments observed in the archaeological record (e.g., widespread use of metal tools from EM onwards, distinctly different social organisation between Palatial and earlier phases) suggest that differences are likely to be observed at least between Neolithic and BA sub-assemblages. To begin, the frequency of cut marks from different types of tool is explored.

6.3.1 Frequency of butchery marks

Frequency of butchery marks is explored by calculating percentages of butchered MaxAU for each MDT, and differentiating between marks depending on the tool that most plausibly inflicted them, as this may be period-specific and/or affect their visibility (section 6.3.2). Thus, based on their morphology, butchery marks were categorised into *cut, chop* and *saw* marks (Table 6:1). Frequencies for each taxon show that all three types are most commonly observed on bones of the MDT, reflecting the overwhelming predominance of the latter in the assemblage as a whole.

Table 6:1 Frequency of cut, chop and saw marks by taxon in Neolithic and Bronze Age contexts (MaxAU; excluding loose teeth and foetal/neonatal specimens; for MDT only, data also presented excluding mandibles and phalanges).

	Neolithic							Bronze Age						
	Cut		Chop		Saw			Cut		Chop		Saw		
	MaxAU	%	MaxAU	%	MaxAU	%	Total	MaxAU	%	MaxAU	%	MaxAU	%	Total
Equid	1	100.0%	-	-	-	-	1	-	-	-	-	-	-	-
Cattle	432	5.6%	10	0.1%	-	-	7712	148	10.4%	26	1.8%	8	0.5%	1424
Pig	151	5.2%	-	-	-	-	2895	235	13.6%	73	4.2%	-	-	1726
Sheep/goat	468	3.8%	3	<0.1%	3	<0.1%	12202	637	10.8%	127	2.1%	2	<0.1%	5911
Dog	3	3.1%	-	-	-	-	97	6	14.6%	-	-	-	-	41
Hare	-	-	-	-	-	-	1	1	100.0%	-	-	-	-	1
Badger	3	3.6%	-	-	-	-	84	-	0.0%	-	-	-	-	7
Fallow deer	-	-	-	-	-	-	2	5	26.3%	-	-	-	-	19
Total	1058	4.6%	13	0.1%	3	<0.1%	22994	1032	11.3%	226	2.5%	10	0.1%	9127
MDT MaxAU Counts Excluding Mandibles & Phalanges														
Cattle	317	6.1%	9	0.2%	-	-	5165	123	11.8%	24	1.8%	8	0.7%	1041
Pig	143	6.0%	-	-	-	-	2389	230	15.2%	73	4.2%	-	-	1510
Sheep/goat	453	4.4%	3	<0.1	3	<0.1	10275	628	11.7%	125	2.3%	2	<0.1	5367

Tests for Cut	Cattle		Pig		Sheep/goat		Tests for chop	Cattle		Pig		Sheep/goat	
	χ^2	p	χ^2	p	χ^2	p		χ^2	p	χ^2	p	χ^2	p
Neo-BA	42.404	0.000	91.425	0.000	291.425	0.000		74.401	0.000	117.698	0.000	233.516	0.000

Overall, a greater frequency of butchery marks is observed in BA compared to Neolithic sub-assemblages. The same groups are also compared excluding phalanges (to ascertain that the result is not a reflection of differential recovery between sub-assemblages) and mandible specimens (which were observed to be unevenly represented between periods, probably due to high fragmentation in Neolithic, and patterns of discard in Palatial contexts) (Table 6:1). The differences are still present when these elements are excluded and are statistically highly significant for both cut and chop marks and for all MDT. In order to verify that these patterns are equally independent of taphonomic processes for individual sub-assemblages (and proceed to their interpretation), the following section explores observed differences taking into account disparate taphonomic histories (treatment by previous analysts, recovery methods, scavenger attrition) and possible differential detection (by this analyst) of stone and metal butchery marks.

6.3.1.1 *Exploring the potential effect of variable taphonomic histories*

In order to address the question of whether differences in frequency of butchery marks are an artefact of variable taphonomic histories, or a product of human carcass processing practices, the following analytical approach is adopted here. Specimens of long bones representing only two types of fragmentation, complete and end-and-shaft (excluding splinters) are selected to explore frequency of observed *cut* marks, and the MDT are analysed separately to explore potential differences in butchery methods and intensity between taxa. The dataset chosen helps

control for various filters, which could arguably have affected the assemblage in the following ways:

- *Choice of butchery mark type*: only specimens with *cut* marks are included, as the frequency of other types – chop and saw – most certainly reflects the *efficacy* and *availability* of certain tool types in different periods (see below);
- *Choice of body parts*: by excluding astragali, calcanea and phalanges, the method controls for differential *recovery* between taxa and excavation campaigns;
- *Choice of fragmentation types*: by excluding *shaft splinters* and *cylinders* the method controls for inflation of 'uncut' specimens, resulting from high fragmentation (as reflected by shaft fragments) and carnivore gnawing (reflected in the formation of cylinders); the exclusion of these types also eliminates the bias introduced by *transport damage* and *selective retention* in the case of the Evans1 'Early' material.

Results are presented in Table 6:2, divided into groups based on date, different storage history and treatment by previous analysts: Evans1 'Unselected', Evans1 'Selected', Evans2, Prepalatial (EMI-MMIA) and Palatial (MMIB-LMIIIB).

Table 6:2 Frequency of cut specimens of long bones by taxon, periods and excavation campaign (MaxAU; MDT only; excluding shaft splinters and cylinders, and neonatal/foetal specimens)

		Neolithic				Bronze Age	
		Evans1 Unselected	Evans1 Selected	Total Evans1	Evans2	Prepalatial EMI-MMIA	Palatial
Cattle	Uncut	190	197	387	568	33	66
		96.0%	92.10%	93.9%	89.4%	86.8%	79.5%
	Cut	8	17	25	67	5	17
		4.0%	7.90%	6.1%	10.6%	13.2%	20.5%
Pig	Uncut	183	143	326	302	115	375
		95.3%	94.70%	95.0%	91.2%	86.5%	81.9%
	Cut	9	8	17	29	18	83
		4.7%	5.30%	5%	8.8%	13.5%	18.1%
Sheep/goat	Uncut	633	576	1209	1368	473	1084
		94.9%	94.40%	94.7%	91.6%	88.9%	81.2%
	Cut	34	34	68	125	59	259
		5.1%	5.60%	5.3%	8.4%	11.1%	18.8%

χ^2 tests for Evans1 Unselected -Selected	χ^2	p
Cattle	2.749	0.097
Pig	0.067	0.796
Sheep/goat	0.143	0.705

First, the effect of treatment by previous analysts is explored for Evans1 material: statistical tests show that there are no significant differences between 'Selected' and 'Unselected' material

for any of the MDT and thus all Evans1 material is usable for the present analysis (Table 6:2). Despite small sample sizes in some cases, comparison of the statistically reliable samples shows a consistently high frequency of *cut* marks in Palatial deposits, less so in Prepalatial and lowest in Neolithic, and suggests that the patterns observed in Table 6:1 are not an artefact of recovery or post-excavation damage and are not readily attributable to scavenger attrition.

Another obvious difference is that between the Evans2 and Evans1 material: frequency of cut marks is higher in the former, although essentially the same chronological span is covered by both. The vast majority of the Evans2 Neolithic sub-assemblage, however, comes from WC and of Evans1 from CC. To explore whether the difference reflects spatial variation, groups from Evans1 CC and Evans2 WC from the same chronological horizon (ENIb-LN/FN) are compared in Table 6:3. Again, because of transport damage and selective retention in the case of the Evans1 sub-assemblage, analysis is restricted to long bones, excluding shaft fragments and end splinters.

Table 6:3 Frequency of cut specimens of long bones by taxon in Evans1 CC and Evans2 WC (MaxAU; MDT only; excluding shaft end and shaft splinters and cylinders, and neonatal/foetal specimens).

		Evans1 CC Str VII-II	Evans2 ENIb-LN WC
Cattle	Uncut	375	407
		94.9%	88.7%
	Cut	20	52
		5.1%	11.3%
Pig	Uncut	304	141
		94.7%	89.8%
	Cut	17	16
		5.3%	10.2%
Sheep/Goat	Uncut	1121	814
		94.7%	91.6%
	Cut	63	75
		5.3%	8.4%
		χ^2	p
χ^2 tests	Cattle	10.796	0.001
	Pig	3.931	0.047
	Sheep/Goat	7.931	0.005

There are highly significant (cattle, sheep/goat) and significant (pig) differences in the frequency of cut marks between the two areas, with WC material exhibiting the higher frequency values. This is doubly interesting given that carnivore gnawing, which might have obscured cut marks, is very high in WC in the earlier phases (ENIb-ENII) and significantly higher than contemporary deposits in CC.

Evidently, there are temporal (between Neolithic and Bronze Age) and spatial differences (between WC and CC during ENIb-LN/FN) that are independent of excavation and post-excavation treatment and probably of post-depositional processes. The extent to which these patterns are consistently repeated through all sub-phases is explored below.

6.3.1.2 *Frequency of cut marks in individual sub-phases*

Section 6.3.1 suggested that differences in frequency of cut marks between Neolithic, Prepalatial and Palatial sub-assemblages are not an effect of recovery or post-excavation treatment and probably not of scavenger attrition, and so should be interpreted in terms of pre-depositional processes. It remains possible, however, that these broad contrasts might be an artefact of averaging highly variable sub-assemblages (subject, *inter alia*, to very different levels of scavenger attrition) within the Neolithic and the BA. In order to explore this possibility, % MaxAU of all MDT combined are presented for each sub-phase and area separately, but in this case all 'fragmentation' types and elements (with the exception of phalanges, to control for differential recovery) are used, as otherwise samples sizes would be too small to be meaningful. Again, only specimens with *cut* marks are used, for the reasons detailed above. Data are presented in two ways: first, a scatter diagram presents the relationship between frequency of cutting and frequency of gnawing for all sub-phases and areas (Figure 6:14). Secondly, two bar charts present frequencies of cut specimens for the Neolithic (Figure 6:15) and Bronze Age (Figure 6:16), distinguishing between sub-assemblages of different sample size. Figure 6:15 demonstrates that Neolithic sub-assemblages exhibit consistently low frequencies of cut marks (3-7.5%), despite great variation in frequencies of attrition. Moreover, with the exception of MN, the frequency is consistently higher in WC deposits than CC. Figure 6:15 suggests that the patterns are significant, as all sub-phases and areas are represented by statistically valid samples with the exception of ENIa-CC (n=342) and ENIc-WC (n=138). It is worthwhile pointing out, however, that the most dramatic difference is observed in the final sub-phase (LN). A broadly similar pattern is observed for Prepalatial bone groups (Figure 6:14): a wide range of frequencies of scavenger attrition, but low frequencies of cut marks (ca. 4-9%), with the exception of the MMIA bone group (13.3%); only two of the sub-phases, however, are represented by statistically valid samples (Figure 6:16).

Palatial sub-assemblages present a slightly more complicated picture. They exhibit a much narrower range of frequency of scavenger attrition (as already observed in Chapter 5), but frequencies of cut marks are consistently higher than in earlier bone groups with similar levels of attrition. On the other hand, there is marked variability in frequency of cut marks between

sub-assemblages, but this may be a result of small sample sizes in several cases (n<100). Nevertheless, each of the Old, New and Final Palatial periods is represented by one or two sub-assemblages large enough to be statistically valid and in each such case a significantly higher frequency of cut marks is observed than in Neolithic and Prepalatial sub-assemblages, with similar or higher levels of scavenger attrition. In conclusion, with due allowance for sample size, the frequency of observed cut marks is consistently high in Palatial and consistently low in Neolithic sub-assemblages; it is consistently low in Prepalatial, with the exception of the latest (MMIA) sub-assemblage, which matches the frequency observed in Palatial deposits.

To clarify whether the high frequency of cuts in MMIA is independent of taphonomic processes, the MMIA bone group (14% gnawed) is compared with two other Prepalatial groups with similar frequency of scavenger attrition: EH EMII-III and WCH (14-20% gnawed). To control for the effects of scavenger attrition, gnawed specimens are excluded and likewise, to control for recovery, phalanges (these groups are comparable in terms of storage history and treatment by other specialists). The results presented in Table 6:4 show a substantially higher frequency of observed cut marks for all MDT in MMIA than in EMI-III bone groups. Although sample sizes are small, the differences are statistically highly significant for cattle and significant for pigs and sheep/goat.

Table 6:4 Frequencies of cut marks in EMI-III and MMIA assemblages (MaxAU; MDT only; excluding loose teeth, phalanges, newborn/foetal and gnawed specimens).

		EMI-III WCH & EH	RRS MMIA
Cattle	Uncut	84	131
		93.3%	81.4%
	Cut	6	30
		6.7%	18.6%
Pig	Uncut	57	134
		95.0%	81.2%
	Cut	3	31
		5.0%	18.8%
Sheep/goat	Uncut	496	434
		94.3%	90.4%
	Cut	30	46
		5.7%	9.6%
χ^2 tests		χ^2	p
	Cattle	6.729	0.009
	Pig	6.521	0.011
	Sheep/goat	5.410	0.020

It should be pointed out that all MMIA material derives from a single context and it is therefore possible that we are seeing here a spatial rather than a temporal difference. On the other hand, the EM sub-assemblage derives from a variety of areas and types of deposits (open, closed, fills,

etc. see Chapter 4), providing grounds for optimism that, if EM assemblages similar to that from MMIA existed, they would have been found [2].

6.3.1.3 *Conclusion*

It is clear from the above that there are differences in frequency of observed *cut* marks between the Neolithic-EM and MMIA-Palatial periods and between the WC and CC components of the Neolithic assemblage. These differences are apparently independent of taphonomic filters and are consistent between the constituent sub-assemblages of these broad groupings. It remains to explore whether these differences are related to changes in the tools used in butchery. For example, the adoption of metal tools may have facilitated more intensive butchery or created more visible butchery marks. To this end, the following sections first summarise the artefactual evidence for the range of tools available in the period under study, and then consider whether this is consistent with the temporal distribution of different types of butchery marks.

6.3.2 Tools used in butchery and bone-/horn-working

6.3.2.1 *The evidence of the artefacts*

In the periods under study, there is a clear chronological distinction in the use of raw materials for tool manufacture: very crudely, *chipped* and *ground stone* tools are typical of the Knossian Neolithic, while, from the EM onwards copper/bronze tools (hence referred to as 'metal') become available (see Chapter 3).

Neolithic *cutting* implements found at Knossos are obsidian (overwhelmingly) and chert/flint (rarely) blades and flakes (J.D. Evans 1964: 233). It is possible that *organic* materials were used in either period – e.g., reeds (Forde 1934: 17) – although it is debatable whether these would have left traces on the bones. The earliest examples of *metal cutting* implements (knives) are known from the EMI cemetery at Aghia Photia, further to the east of the island (Day *et al.* 1998: 145) and EMII Koumasa (Xanthoudides 1924: 47, pl. XXIXb) and examples from Knossos itself are known from Palatial contexts[3] at the RR and MUM.

Chopping implements in use during the Neolithic are stone axes/adzes, ubiquitous in Knossian Neolithic deposits (J.D. Evans 1964: 229), and, in the Bronze Age, bronze axes and cleavers. Whereas the earliest known *metal* axe at Knossos was found in an LN/FN context (A. Evans

[2] It should be noted here that, because of small sample sizes of EMI and EMIII material, the EMI-III group in fact best represents EMII; EMIIB should (on present evidence), therefore, be a more reliable *terminus post quem* for the low frequency of cut marks.

[3] Evely's study does not provide a catalogue of finds and at present an exhaustive research of finds of this type from Knossos is not possible.

1928: 14, fig. 37), cleavers are known from late BA contexts, several from LMIIIA-B burials at the cemetery of Armenoi (Tzedakis and Martlew 1999). Metal cleavers and axes would have allowed faster dismembering, by chopping through, rather than cutting round or between articulations, while chopping through the shaft of long bones would have given access to the marrow cavity, but it is not certain that stone axes could have been used to perform either of the above tasks. Their unsuitability may be reflected in the rarity of chop marks in Neolithic contexts (Table 6:1). Indeed, it is possible that for bone cracking (in order to access within-bone nutrients), stones and other bones could have been employed, as is widely documented ethnographically (e.g., Binford 1981: 142, Kent 1993).

No specialised tools for *sawing* can be identified in the Neolithic chipped stone tool kit at Knossos and it is likely that ordinary chipped stone tools would have been used to achieve this effect (stone blades/flakes). 'Real' saws, i.e. implements with a *serrated* cutting edge made of copper alloys first appear in Prepalatial funerary contexts and more specialised types of varying sizes develop throughout the BA (Evely 1993: 26-39).

Artefactual evidence thus suggests a fairly clear break between dependence on stone cutting tools and axes in the Neolithic and the use of metal implements (knives, cleavers and saws) in the Bronze Age. Artefactual evidence alone may be misleading, however, if early finds of metal knives or axes represent prestige items rather than practical tools, if recycling obscured the existence of early tools in regular use, or periods/area specific cultural practices (e.g., deposition of such artefacts in funerary contexts) influence the visibility of artefacts in the archaeological record. For the reasons, an attempt will be made to verify the picture emerging from artefacts with evidence from butchery marks.

6.3.2.2 *The evidence of butchery marks on bone*

Table 6:1 showed that *cut* marks, presumably inflicted by stone and metal knives, are much commoner, on all the MDT and in both the Neolithic and BA, than chop marks; the latter (presumably inflicted by stone axes) are very rare in the Neolithic, but considerably commoner in BA contexts (when metal axes and cleavers become available). Table 6:5 presents frequencies of cut and chop marks in more detail, broken down by taxon and period; in light of the conclusions of section 6.3.1.3, the Prepalatial material is subdivided into EMI-III and MMIA. Frequencies are calculated both for all body parts (except loose teeth) and excluding mandibles and phalanges (for reasons outlined in section 6.3.1).

Table 6:5 Frequencies of cut and chop marks by taxon and period (MaxAU; excluding loose teeth, foetal/neonatal specimens and [right] mandibles and phalanges).

		Incl. Mandibles and phalanges				Excl. mandibles and phalanges			
		Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial
Chopped	Cattle	0.1%	0.0%	1.3%	2.9%	0.2%	0.0%	1.6%	3.7%
	Pig	0.0%	0.0%	0.5%	5.8%	0.0%	0.0%	0.6%	6.7%
	Sheep/Goat	<0.1%	0.4%	0.9%	3.4%	<0.1%	0.4%	1.0%	3.6%
Cut	Cattle	5.6%	3.8%	17.5%	11.6%	6.1%	4.4%	18.0%	13.6%
	Pig	5.2%	5.9%	16.9%	14.9%	6.0%	6.8%	18.9%	16.6%
	Sheep/Goat	3.8%	4.4%	10.2%	14.6%	4.4%	5.0%	10.6%	15.7%
Total	Cattle	7712	394	223	807	5165	293	183	565
	Pig	2895	290	201	1235	2389	250	180	1080
	Sheep/Goat	12202	1985	549	3377	10275	1752	517	3098

The rarity of chop marks in the Neolithic may reflect the unsuitability of stone axes for chopping through bone, as already mentioned above; joints were presumably disarticulated by cutting rather than chopping, while within-bone nutrients may have been accessed by an action more akin to smashing, which would not necessarily leave identifiable marks. The advent of metal chopping tools, which leave unambiguous marks thus making identification more straightforward, may partly account for the increased frequency of chopping in BA contexts. Although chopping tools (at least axes) were available in the Prepalatial period, however, chop marks are no more frequent in EMI-III than in the Neolithic. Chop marks are considerably more frequent in MMIA and the Palatial period, an increase which might plausibly be attributed to greater availability of heavy metal tools in MM and LM. On the other hand, it is also worthy of note that MMIA and Palatial chop marks are not, as might have been expected, found preferentially on the largest animals, i.e. cattle, but are fairly evenly represented on the three MDT (Table 6:5). This suggests that the use of chopping tools was not dictated purely by functional considerations of efficiency.

Knife marks are the predominant form of butchery trace found throughout the Neolithic and Bronze Age. There are grounds for optimism that cutting marks inflicted by stone and metal knives can be distinguished quite reliably, but unfortunately it was not possible to record this variable systematically due to time constraints and initial lack of familiarity with the diagnostic criteria (Chapter 4; but see also above section 6.3.1.3). Examination of a sample of LN and EM cut marks, however, failed to find any evidence of morphologically 'stone' cut marks in EM assemblages, suggesting that artefactual evidence for the transition from stone to metal knives is essentially reliable. In this case, it becomes clear that the increase in frequency of cut marks, between EMIII and MMIA, is related neither to the adoption of more efficient metal tools nor to the greater visibility of metal-inflicted cuts.

Finally, saw marks are rare and restricted to specific taxa (sheep, goat and cattle) and, unlike cut and chop marks, to specific body parts (see below section 6.8.2). For sheep/goat, only one proximal tibia and one distal sheep humerus from Neolithic Stratum IIIb, one proximal radius from an LN deposit, and two goat horncores of BA date (EMIII and LMIA contexts) bore such marks. On cattle, saw marks were observed only in BA (EMIII-LMIB) contexts, where they are concentrated on horncores (5 specimens), with three examples on long bones (proximal radius, proximal femur, and distal metapodial). Saws were evidently not used in the BA as a generalised butchery tool, as is the case in Roman and later specialist butchery. The rarity, location and distribution of sawing, as well as the care with which the action was performed (Figure 6:30h), suggest that it was employed in extracting raw material (bone and horn) for craft-working; chopping tools, available in the periods from which sawn examples derive, enable less time-consuming but also less precise sectioning of bone and horn. Further independent evidence in support of this argument is presented in section 6.8.2.

6.3.2.3 *Conclusion*

The range of types of butchery marks found corresponds roughly with the artefactual evidence for the types of tools available, while providing additional evidence for the uses to which these tools were put. It is evident, however, that the availability of tools did not dictate patterns of use: saws were apparently not used in butchery, but rather in bone- and horn-working; metal cleavers were used far less frequently than knives and were not used preferentially to butcher larger animals; and the increased intensity of cutting and chopping from MMIA onwards is unrelated to the availability of metal knives or, probably, cleavers. In order to explore these emerging patterns further to clarify their meaning, the following section goes on to discuss the *placement* of butchery marks on the skeletons of MDT.

6.3.3 Stages of carcass processing

6.3.3.1 *Methods and overall pattern*

This section uses butchery (i.e. cut and chop) marks to explore carcass processing of MDT, following Binford's classification of marks based on their placement on the skeleton (Binford 1981: 96-142). The analysis follows the probable order of carcass processing, i.e. skinning, then dismembering and finally filleting, and looks at the frequency and distribution on the skeleton of each of these types for each of the MDT diachronically. Chronological divisions are necessarily rather coarse – Neolithic, Prepalatial (divided into EMI-III and MMIA due to the conclusions reached above), Palatial – as numbers of observed butchery marks prohibit a detailed study of individual sub-phases and areas. No distinction is drawn between tool types,

from the present analysis, as high fragmentation has led to the loss in most cases of the parts of the mandible where such marks are likely to have occurred; indeed only one example of a skinning mark on a mandible was identified in the whole of the assemblage. Articular end specimens of metapodials (complete or fragmentary) are also excluded, as skinning marks will only occur on the shaft, and so are third phalanges, on which butchery marks were extremely infrequent and which also suffered heavy losses due to partial recovery. Frequency is measured as the percentage MaxAU of specimens of the selected elements bearing skinning marks. Frequency of gnawing is also calculated for each element to investigate the possibility that gnawing marks have obscured butchery traces. The results are presented in Table 6:7.

Table 6:7 Frequency of skinning and gnawing marks by period, taxon and body part (MaxAU; excluding loose teeth and neonatal/foetal specimens; butchery data also exclude third phalanges, metapodial end fragments and sawn specimens).

		Neolithic		Prepalatial EMI-III		Prepalatial: MMIA		Palatial	
		Skinned	Gnawed	Skinned	Gnawed	Skinned	Gnawed	Skinned	Gnawed
Cattle	HC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%	0.0%
	MC	1.3%	26.4%	0.0%	10.3%	8.3%	25.0%	4.8%	8.1%
	MT	1.4%	26.4%	0.0%	23.8%	0.0%	16.7%	5.2%	13.2%
	PH1	2.1%	22.4%	0.0%	8.1%	0.0%	7.7%	7.4%	4.9%
	PH2	9.5%	19.9%	3.2%	9.1%	41.7%	16.7%	5.1%	6.3%
	Total	2952/106	2332/ 717	163/1	101/13	39/6	38/7	331/21	324/26
Pig	MC	0.0%	40.0%	0.0%	22.2%	0.0%	7.7%	0.0%	11.2%
	MT	0.0%	32.5%	0.0%	61.5%	0.0%	0.0%	0.0%	0.9%
	PH1	1.7%	23.3%	0.0%	36.4%	0.0%	0.0%	0.0%	2.2%
	PH2	0.0%	26.8%	0.0%	33.3%	0.0%	0.0%	6.7%	6.7%
	Total	567/2	376/189	46/0	21/15	30/0	29/1	279/1	261/15
Sheep/ Goat	HC	1.9%	6.6%	0.0%	0.0%	0.0%	0.0%	10.3%	0.0%
	MC	0.2%	32.1%	0.0%	33.1%	0.0%	26.9%	2.7%	8.9%
	MT	0.3%	29.5%	0.0%	36.8%	4.4%	8.9%	3.3%	15.5%
	PH1	0.7%	21.1%	0.0%	18.2%	20.0%	0.0%	4.3%	0.0%
	PH2	0.0%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Total	2921/11	2109/814	396/0	219/95	125/3	106/22	654/24	617/61

The first observation is that several samples are too small for detailed analysis and only a few patterns can be suggested with any confidence, the problem being most acute for all MDT in the Prepalatial sub-assemblage. Overall, skinning marks are strikingly rare on pig and only slightly less so on sheep/goat. Only three examples of skinning marks were observed on pig remains from the whole assemblage. Skinning marks on sheep/goat occur on metapodials, first phalanges and horncores in the Neolithic, although infrequently, and on the same elements but slightly more frequently in the Palatial (Figure 6:17). The rarity of skinning marks on pig and sheep/goat can be attributed to post-depositional processes. Phalanges of pigs and sheep/goat have been more or less severely affected by partial recovery in all sub-assemblages, and this is

probably compounded in some cases by high levels of scavenger attrition. Horncores (anyway absent in pigs) are rare in the assemblage as a whole, most probably due to their fragility; indeed all ovicaprid horncores bearing butchery marks were identified as goats, which are considerably more robust than sheep.

The most reliable conclusions can be drawn from cattle remains, least affected by poor recovery and scavenger attrition, and present in numbers more or less large enough to allow for statistically valid inferences. The element on which skinning marks most commonly occur in the Neolithic and Prepalatial is the second phalanx, while such marks occur rarely on other elements (Neolithic) or not at all (most of the Prepalatial). On the contrary, skinning marks are more evenly distributed on all relevant elements in the Palatial (Figure 6:18).

6.3.3.2.1 Conclusion

Overall, skinning is observed more rarely than other types of butchery marks because it occurs on a smaller range of elements and several of these are especially vulnerable to post-depositional processes. The wider anatomical distribution of skinning marks on cattle in the Palatial sub-assemblage suggests less meticulous skinning of carcasses (i.e. retrieval of slightly less of the skin) and/or discard in primary butchery of slightly more of the head and foot. For example, Neolithic and Prepalatial cattle were usually skinned down to the second phalanx, whereas Palatial cattle are more frequently skinned down to only the first phalanx or even to the metapodials. This implies more rapid and less thorough processing of cattle carcasses in Palatial than earlier contexts.

The rarity of skinning marks in pig could potentially be interpreted in terms of consumption of pig carcasses unskinned, as is commonly the practice today with younger pigs. In the case of sheep/goats (and possibly pigs too), however, the overall scarcity of skinning marks is most parsimoniously attributed to the relative rarity of recovered phalanges, leaving open the possibility that the foot was commonly skinned out also in these smaller animals. Whether sheep/goats were less thoroughly skinned in the Palatial period than earlier is difficult to assess because of the small sample size, but skinning of the foot was concentrated on the first phalanx in the Neolithic and was more evenly distributed between the first phalanx and metapodials in Palatial contexts. Finally, it should be noted that some of the sharp increase, in the Palatial period, in skinning marks around the horn in both cattle and sheep/goat, is attributable to the chopping off of the horn and may reflect the availability of metal cleavers. In other respects, however, the less thorough skinning of Palatial carcasses stands in sharp contrast to the probable availability of superior butchery tools in this period.

6.3.3.3 *Dismembering*

Examination of dismembering concentrates on articular areas (where separation is easiest with the tools available), and thus includes only those fragment types with at least part of an articulation (i.e. shaft fragments and cylinders are excluded). This selection thus allows for the use of all material, including the Evans1 'Selected' (in which cylinders and shaft fragments are absent/under-represented due to destruction and selective retention). MaxAU of adjacent articulations (e.g., distal femur and proximal tibia) are combined to provide a composite picture of dismembering activity around a joint. In order to assess the possible impact of scavenger attrition, frequencies of butchered MaxAU are calculated both for all specimens and for 'non-gnawed' specimens only, while the frequency of gnawed specimens for each of these areas is also presented (Table 6:8).

Table 6:8 Frequency of dismembering and gnawing marks by period, taxon and articulation (MaxAU; excluding foetal/neonatal specimens, loose teeth, shaft splinters and cylinders; frequency of dismembering presented both excluding and including gnawed specimens; for each phase, frequencies ≥50% of highest value are shaded dark, 25-49% shaded light, <25% unshaded).

		Neolithic			EMI-III			MMIA			Palatial		
		Dismembered			Dismembered			Dismembered			Dismembered		
		Excl Gnaw.	Incl Gnaw.	% Gnawed	Excl Gnaw.	Incl Gnaw.	% Gnawed	Excl Gnaw.	Incl Gnaw.	% Gnawed	Excl Gnaw.	Incl Gnaw.	% Gnawed
Cattle	MD	0.4	0.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sc/Hp	4.3	3.8	19.6	16.7	5.9	64.7	36.8	36.6	0.0	16.0	14.3	10.7
	Hd/Rp/U	13.6	12.9	37.3	11.1	5.7	48.6	10.0	8.3	16.7	11.1	11.9	12.2
	Rd/Mcp	2.4	2.0	23.0	5.0	3.2	35.5	14.3	9.1	36.4	2.9	2.6	10.5
	Pe/Fp	3.7	4.1	29.0	9.1	3.4	62.1	7.1	20.0	30.0	20.0	17.9	17.9
	Fd/Tp	1.4	1.7	25.7	0.0	0.0	25.0	0.0	0.0	12.0	22.6	20.0	22.5
	Td/A/C/MTp	9.2	8.8	27.4	4.5	2.9	68.1	22.0	23.3	4.7	20.2	21.2	8.8
	Mpd/Ph1	1.0	0.8	21.9	0.0	0.0	38.0	0.0	0.0	5.0	2.5	2.3	6.0
	Ph2	3.0	2.5	19.8	5.0	3.2	35.5	20.0	25.0	16.7	2.7	2.5	6.3
		4451/ 215	**5936/ 290**	**4666/ 1560**	**154/ 7**	**304/ 8**	**161/ 151**	**151/ 24**	**172/ 29**	**175/ 26**	**565/ 63**	**631/ 71**	**628/ 74**
Pig	MD	0.0	0.0	2.3	0.0	0.0	17.4	0.0	0.0	0.0	0.0	0.0	0.0
	Sc/Hp	7.0	6.8	35.2	6.7	3.0	51.5	25.0	22.2	29.6	27.1	26.6	15.1
	Hd/Rp/U	15.1	12.5	40.3	8.6	16.7	64.6	39.1	20.4	24.1	33.5	30.3	15.0
	Rd/Mcp	0.0	0.0	39.6	0.0	0.0	45.5	0.0	0.0	7.1	4.7	4.3	7.6
	Pe/Fp	5.6	4.3	39.8	7.7	4.8	47.6	28.6	23.5	5.9	20.9	20.3	6.5
	Fd/Tp	0.9	0.7	18.8	12.5	8.3	25.0	0.0	7.1	50.0	19.8	16.9	13.1
	Td/A/C/MTp	6.7	4.6	38.9	3.8	3.1	59.4	25.0	12.1	12.1	15.4	14.1	14.5
	Mpd/Ph1	0.0	0.0	28.4	0.0	0.0	52.2	0.0	0.0	0.0	0.0	0.0	3.9
	Ph2	0.0	0.0	26.2		0.0	50.0	0.0	0.0	0.0	0.0	0.0	6.7
		1661/ 93	**2456/ 125**	**1754/ 827**	**97/7**	**195/ 12**	**104/ 103**	**136/ 22**	**166/ 26**	**158/ 34**	**818/ 158**	**937/ 174**	**976/ 135**
Sheep/Goat	MD	0.0	0.0	4.4	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0
	Sc/Hp	2.5	2.0	18.4	5.3	3.3	38.0	20.0	18.2	9.1	15.6	14.5	9.1
	Hd/Rp/U	12.6	11.2	31.1	20.0	17.5	52.0	21.8	20.8	15.8	23.9	22.8	11.4
	Rd/Mcp	0.9	0.8	28.9	5.7	5.4	37.5	5.1	6.0	22.0	6.2	5.7	7.9
	Pe/Fp	4.8	4.4	22.4	7.3	6.9	36.8	10.0	9.7	3.2	15.8	15.5	3.3
	Fd/Tp	1.1	0.9	12.5	0.0	0.0	45.0	0.0	0.0	6.7	13.2	12.7	5.8
	Td/A/C/MTp	2.5	2.4	22.6	3.5	2.7	41.2	1.1	1.0	7.3	9.2	8.8	8.6
	Mpd/Ph1	0.4	0.3	22.8	0.0	0.0	36.5	0.0	0.0	14.5	0.9	1.2	5.9
	Ph2	0.0	0.0	8.5	0.0	0.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0
		7788/ 283	**9980/ 349**	**8071/ 2258**	**755/ 47**	**1194/ 77**	**791/ 480**	**363/ 34**	**411/ 38**	**397/ 52**	**2363/ 327**	**2652/ 342**	**2690/ 214**

First, there appears to be no relation between the frequencies of dismembering marks and gnawing within the same articulation. There are several instances where the highest frequencies of marks (e.g., Neolithic cattle and pig Hd/Rp/U) are associated with the highest levels of gnawing. The frequency of dismembering marks is little affected by the inclusion or exclusion of gnawed specimens with the exception of small samples (e.g., EMI-III cattle and pigs). It

seems legitimate, therefore, to base the analysis on the counts including gnawed specimens, which provide larger – and so statistically more reliable – samples.

In order to explore differences in frequency between different areas of the body within each taxon, the following approach is adopted. The highest frequency value is taken as 100% and based on it other parts of the carcass are attributed to three categories: 1) those ≥ 50% of the highest value (highlighted dark grey in Table 6:8); 2) those 25-49% of the highest value (highlighted light grey); and 3) those <25% of the highest value (white). Moreover, the different frequencies are colour coded in Figure 6:19 for cattle, Figure 6:20 for pigs and Figure 6:21 for sheep/goats, and patterns of frequency and anatomical distribution of dismembering examined for each taxon across periods.

6.3.3.3.1 Cattle

Figure 6:19 shows that, for cattle carcasses, the anatomical distribution of dismembering marks varies greatly between periods. In the Neolithic, the elbow and ankle are most frequently dismembered, followed by the shoulder and hip. In the Palatial period, the shoulder, elbow, hip, knee and ankle are all frequently dismembered, suggesting that sectioning of cattle carcasses was more intensive. In the Prepalatial EMI-III cattle sectioning broadly resembles that for the Neolithic in being most commonly distributed on a narrow range of articulations, but because of the small sample the pattern is not very clear or reliable. MMIA cattle are closer to the Palatial pattern: high frequencies of dismembering marks occur over a wider range of articulations.

6.3.3.3.2 Pig

A broadly similar picture is observed for pig (Figure 6:20): in Neolithic pig remains, the only frequently butchered articulation is the elbow, followed by the shoulder, hip, and ankle. In the Palatial period, sectioning is very frequent for the shoulder, elbow, hip and knee, and moderately so for the ankle. In EMI-III sectioning appears intermediate between the Neolithic and Palatial patterns, but once again the sample size is small. MMIA pig shows a higher frequency of dismembering marks, more evenly distributed across articulations, resembling more the Palatial pattern.

6.3.3.3.3 Sheep/Goat

Sheep/goat show a similar temporal pattern to the other two taxa. Neolithic dismembering is concentrated at the elbow and secondarily around the hip, but is very infrequent around other joints. At the other extreme, in Palatial remains, dismembering occurs very frequently at the shoulder, elbow, hip and knee, and moderately so at the 'wrist' and ankle. In the Prepalatial, an intermediate pattern is again observed, with the elbow most frequently dismembered and the 'wrist' and hip moderately so, the only difference between EMI-III and MMIA being that the frequency of dismembering around the shoulder is very high in the latter, but only moderately so in the former.

6.3.3.3.4 Conclusion

The overall pattern observed for the four chronological horizons is broadly similar for all MDT. In the Neolithic, dismembering marks are limited to fewer articular areas of the skeleton as well as being less frequent, whereas in Palatial material dismembering marks are both a lot more frequent *and* fairly equally distributed on almost all articulations of the front and hind limb of all MDT. Prepalatial butchery appears to represent an intermediate stage in this process towards more intensive sectioning of the carcass, with EM material closer in character to Neolithic and MMIA closer to Palatial.

Two observations should be made here concerning extremities. The great fragility of mandibular hinges, the area where dismembering marks for the mandible are likely to occur, is the safest explanation for the rarity/absence of dismembering marks on this part of the skeleton (a similar cause was suggested for the almost entire absence of mandibular skinning marks in section 6.3.3.2). A more complex picture is presented by phalanges and distal metapodials of pigs and sheep/goats. In some cases, sample sizes for these anatomical units are too small – most probably as a result of partial recovery – and therefore unreliable (e.g., Prepalatial pig phalanges, pig distal metapodials and sheep/goat phalanges; Palatial pig phalanges, pig distal metapodials, and sheep/goat second and third phalanges). In most other cases, however, samples are large enough to suggest that the rarity/absence of dismembering marks around these joints is not merely a reflection of partial recovery, implying that the separation of the lower leg was mostly round the ankle, and not lower down the foot for the medium-sized taxa. Finally, it should be noted that the intensity of dismembering is broadly similar for all MDT, despite the obvious contrast in carcass size between cattle, on the one hand, and pigs and sheep/goats, on the other. The possible significance of this will be considered below after examination of the evidence for filleting.

6.3.3.4 *Filleting*

Study of filleting, i.e. removal of meat, concentrates on long bones, scapula and pelvis. Frequencies are presented for each element separately, except for radius and ulna which are combined, as filleting marks are expected to occur mainly on the shaft of a long bone and 'blade' of flat bones like scapula and pelvis. Of fragment types, end only specimens (complete or fragmentary) are excluded, since it is not likely for marks to be inflicted on these areas during filleting. Evans1 'Selected' material is included because selective destruction and discard of shaft fragments and cylinders does not affect the frequencies of filleting marks overall in the Neolithic assemblage. Table 6:9 shows the frequencies of filleting marks – both including and excluding gnawed specimens – and of gnawing by taxon, anatomical area and period.

Table 6:9 Frequency of filleting and gnawing marks by period, taxon and body part (MaxAU; excluding foetal/neonatal specimens, loose teeth, and end-only specimens; frequency of filleting presented both excluding and including gnawed specimens).

		Neolithic			EMI-III			MMIA			Palatial		
		% Filleting		% Gnawed	% Filleting		% Gnawed	% Filleting		% Gnawed	% Filleting		% Gnawed
		Include Gnawed	Exclude Gnawed		Filleting Incl Gn	Filleting Excl Gn		Include Gnawed	Exclude Gnawed		Include Gnawed	Exclude Gnawed	
Cattle	Md	0.8	0.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0	**20.0**	20.0	0
	Sc	1.1	1.3	18.6	0.0	0.0	62.5	0.0	0.0	0.0	8.3	8.3	0
	Hp/Hd	**1.6**	2.2	34.1	0.0	0.0	50.0	3.0	3.4	12.1	3.2	3.4	4.8
	Rp/U/Rd	1.2	1.2	25.7	**2.7**	5.6	51.4	4.5	5.3	13.6	1.7	2.0	18.3
	Pe	0.2	0.0	27.3	0.0	0.0	64.7	0.0	0.0	0.0	6.7	4.0	16.7
	Fp/Fd	1.3	1.3	17.6	0.0	0.0	70.0	**22.2**	33.3	33.3	8.9	11.4	22.2
	Tp/Td	0.7	0.4	14.0	0.0	0.0	63.6	4.5	5.0	9.1	6.3	6.5	3.1
	MPp/MPd	0.4	0.4	26.9	2.6	4.8	48.0	15.0	7.1	20.0	2.1	2.4	12.1
		4546/38	3480/30		219/3	101/3		127/8	108/8		375/17	328/16	
Pig	Md	1.3	1.3	2.3	0.0	0.0	17.4	0.0	0.0	0.0	4.4	4.4	0.0
	Sc	0.7	0.5	34.3	3.2	0.0	51.6	0.0	0.0	30.8	6.1	3.9	22.7
	Hp/Hd	0.5	0.5	45.7	0.0	0.0	65.3	4.7	6.5	27.9	5.8	6.6	20.4
	Rp/U/Rd	1.1	1.6	33.8	**5.7**	0.0	62.9	6.5	7.4	12.9	5.5	5.5	11.7
	Pe	0.4	0.7	40.9	0.0	0.0	60.0	**14.3**	15.4	7.1	**19.4**	19.6	9.7
	Fp/Fd	1.3	0.8	24.5	**5.7**	0.0	62.9	5.9	10.0	41.2	11.3	11.3	7.3
	Tp/Td	**1.5**	2.1	25.8	0.0	0.0	45.5	4.5	7.1	36.4	6.2	6.9	20.9
	MPp/MPd	0.0	0.0	37.0	0.0	0.0	63.0	0.0	0.0	3.2	1.4	1.5	7.8
		2427/19	1656/16		245/5	113/0		181/8	144/8		962/64	839/57	
Sheep/ Goat	Md	0.8	0.9	6.0	0.0	0.0	5.8	0.0	0.0	0.0	1.5	1.5	0.0
	Sc	0.2	0.2	13.0	0.0	0.0	39.3	8.7	5.0	12.5	7.6	7.9	11.5
	Hp/Hd	1.3	1.7	40.6	1.0	2.0	48.8	8.0	6.2	19.0	6.6	6.5	12.5
	Rp/U/Rd	2.2	2.3	28.3	0.3	0.7	52.1	2.7	1.6	14.5	5.4	5.7	8.4
	Pe	**2.3**	2.1	25.3	0.0	0.0	37.7	0.0	0.0	5.3	5.2	5.3	2.4
	Fp/Fd	0.4	0.4	12.9	**2.7**	4.5	40.4	**6.9**	7.1	3.2	**18.5**	18.3	4.6
	Tp/Td	0.5	0.5	21.7	0.6	1.1	47.5	3.0	3.3	9.4	8.9	8.7	7.0
	MPp/MPd	0.1	0.1	31.0	0.0	0.0	49.1	0.0	0.0	19.6	1.0	1.1	12.1
		10758/103	8149/81		1750/10	987/10		500/18	435/13		2617/199	2397/185	

As for dismembering, Table 6:9 shows that gnawing does not seem to affect the visibility and thus frequencies of marks on individual elements. In fact, additional marks have been observed on gnawed specimens, discussion will concentrate on the larger samples including these. On the other hand, filleting marks are considerably less frequent than dismembering, and interpretations of the data have to be suggested with even greater caution.

The following can be safely suggested: filleting marks are rare in Neolithic and EMI-III, but significantly more frequent in MMIA and Palatial bone groups. Samples are small to compare MDT for the earlier periods, but in Palatial material frequency of filleting is significantly higher ($p=0.043$, $\chi^2=4.084$) for sheep/goat than for the larger cattle; pig is almost as frequently filleted as sheep/goat. In terms of their distribution on skeletal elements, filleting marks occur infrequently on all examined elements in the Neolithic but with varying frequencies in the Palatial. Sample sizes are too small to explore distribution in Prepalatial bone groups. More detailed observations per taxon are possible for Palatial bone groups, where samples are in most cases large enough to be of statistical significance. Allowing for small sample size, Palatial cattle appear to be more intensively filleted on meatier parts (scapula, pelvis, femur and tibia). Pelves and femora are most frequently filleted in pig, other body parts only moderately so. Similarly, for sheep/goat, filleting occurs most frequently on femora and moderately on other body parts. The difference between pig and sheep/goat in relation to the pelvis may be due to the fragility of this body part in sheep/goat.

6.3.3.5 *Looking at placement of butchery marks in more detail*

During recording, the exact location of butchery marks was noted on outlines of each of the recordable elements. The aim was to attempt eventually a more detailed analysis than that allowed by the grouping of marks into skinning, dismembering and filleting. As is often the case, however, only a fraction of the recorded material bore butchery marks, making up a sample too small for very detailed exploration of chronological and spatial patterning. It is possible, however, to explore the potential of this type of data, by selecting a subset providing reasonably large samples. The rationale of the selection is as follows. *Dismembering* of the '*elbow*' joint, consisting of the distal humerus, proximal radius and ulna, is chosen from *Neolithic* and *Palatial* contexts, which provide large enough samples for analysis. Dismembering is the most frequent type of mark and potentially reflects scales of consumption and/or types of preparation. The 'elbow' joint, on the other hand, is well represented in the whole assemblage, as it consists of robust and highly identifiable parts and early fusing articular ends, which are relatively resistant to post-depositional biases (such as partial recovery and

scavenger attrition). The analysis is based on the frequency of butchery marks at particular locations around this articulation. Their interpretation is based on the information provided by Binford's actualistic study (Binford 1981). It is expected that patterns will at least reflect the different potential of stone and metal tools in performing certain tasks, especially in cutting inaccessible areas of the articulation, while standardisation beyond that imposed by anatomical configuration might be encountered in Palatial material if butchery was carried out by specialists.

The exact locations of the (cut and chop) marks observed are shown in Figure 6:22.

The following observations can be made. First, cuts can be found around both the distal humerus and proximal radius and also on the olecranon of the ulna (Figure 6:22). Secondly, all cuts observed around the proximal radius articulation (including the olecranon) are common in all periods and taxa, different frequencies simply reflecting variable representation of this anatomical part in the various sub-assemblages (not tabulated). One striking difference is apparent, however, in the case of marks on the distal humerus. Cuts observed can be divided into two anatomical sub-groups (Table 6:10; Figure 6:23):

1. Group 1: marks on the articular surface itself (cuts Hd-1, Hd-4 & 4a); these were observed only (with a single exception) on Palatial pig and sheep/goat specimens;
2. Group 2: marks on the medial and lateral sides of the articular area and also on the anterior and posterior faces of the distal shaft (i.e. proximal of the articular area); these were observed in all sub-phases and MDT.

Table 6:10 Numbers of different types of dismembering mark on Hd by taxon and period (MaxAU; regular fonts: cut; bold fonts: chop).

		Cattle				Pig				Sheep/Goat			
		Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial
Group 1	Hd-1		1						3	1	1		24
	Hd-1b								1	2		1	5
	Hd-1d									1			2
	Hd-4a								4				
	Hd-4								*1*			*1*	*2*
	Total	0	1	0	0	0	0	0	9	4	1	2	33
Group 2	Hd-2	24	2		4+1	18	3	1	18+2	30	13	4	21+2
	Hd-2a				1				1				
	Hd-2b	1						1	1	9		1	1
	Hd-2c	13		1		6	1		4	8	1	2	7
	Hd-2d	4						1	5	8		3	2
	Hd-2e	3								1	1	1	1
	Hd-2f	1								10			1
	Hd-2g	6				2				14	1		2
	Hd-2h	2								3	1		1
	Hd-2i	2				1				8			
	Hd-3	5							1	1			2
	Hd-3a												1
	Hd-3b	1											
	Hd-8b	4				4			1	3			
	Hd-8c									4			
	Hd-9					1				1	1		1
	Hd-10	3			1				2	1	1		3
	Hd-10b										2		
	Hd-12				2				1				1
	Hd-12a								1				
	Hd-13								1				1
	Hd-14								1				4
	Hd-16					1							
	Hd-17												1
	Hd-18												2
	Hd-19	1								6	1		1
	Hd-19b	1											
	Hd-20								1				1
	Total	71	2	1	9	33	4	3	40	107	22	11	56
	Hs-6							1					
	Hs-6b	2				2				2			
	Total	2	0	0	0	2	0	1	0	2	0	0	0

As Binford (1981) observed, cut marks on the articular surface (Group 1) can only be inflicted by inserting a long, thin object (e.g., a metal knife) between the distal humerus and proximal radius, in order to separate these two bones. Group 2 cut marks, on the other hand, may have been inflicted by short cutting tools (e.g., chipped stone flakes or blades) in the course of severing the soft tissues surrounding the elbow joint. Such marks suggest cutting around the

joint from all aspects with the dual purpose of freeing the articulation and severing muscle from the bone.

The suggestion that these two anatomically defined sub-groups represent alternative strategies for dismembering is reinforced by considering the associations between different types of cut marks on specimens with multiple cut marks. Within each sub-group, different types of cut marks frequently co-occur, but co-occurrence between the sub-groups is restricted to eight cases in which Hd-1 marks are associated with Hd-2 marks. In these few cases, Hd-2 marks may have been inflicted in the course of severing connecting tissues proximal to the articulation in order to free up the joint for Hd-1 incision between distal humerus and distal radius.

Group 1 marks occur overwhelmingly in BA contexts, and given Binford's proposition that such marks are possible only when using long pointed tools, i.e. metal knives, their extreme rarity from Neolithic contexts is not surprising. On the other hand, given that cleavers were available which are occasionally used for dismembering these animals, it is interesting that more precise butchery is sometimes employed to section the carcass in this particular fashion, rather than hacking through the bone. More importantly, Group 1 marks occur only on the medium-sized taxa, i.e. pigs and sheep/goats. The infrequency, however, of cattle remains in BA contexts, and thus rarity of butchered specimens, makes it difficult to draw comparisons with the Neolithic for this taxon. This apparent peculiarity is further explored below in the context of fragmentation patterns.

6.3.3.6 *Summary*

In this section, butchery was explored in terms of its frequency, tools used and placement of butchery marks on the skeleton, comparing different periods and MDT. Butchery marks were considerably more frequent on bones of all MDT in Palatial assemblages compared to Neolithic and Prepalatial ones, with the exception of the latest Prepalatial phase (MMIA). These patterns were consistent between sub-phases within the two broad chronological groups (the Neolithic-EMIII and MMIA-Palatial) and independent of differences in frequency of carnivore gnawing (Table 6:11). One potentially meaningful spatial difference was observed between material from CC and WC, which was most marked in the LN (whether material of this date from Evans1 CC is combined with Evans2 CC or not).

Knife marks were the most common type throughout, while chop marks are significantly more frequent in Palatial deposits compared to Neolithic and Prepalatial. These patterns most probably reflect availability of tools, although it is curious that chopping tools are not more frequently used in the butchery of the larger cattle. Sawing marks were very rare and restricted

to particular parts of the skeleton and taxa (sheep, goats and cattle), suggesting a more specialised use, probably unrelated to butchery *per se*.

Table 6:11 Frequencies of butchery marks by stage of carcass processing, taxon and period (MaxAU).

	Cattle				Pig				Sheep/Goat			
	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial
Uncut/other cut	2952	163	39	331	567	46	30	279	2921	396	125	654
	96.5%	99.4%	86.7%	94.0%	99.6%	100.0%	100.0%	99.6%	99.6%	100.0%	97.7%	96.5%
Skinning	106	1	6	21	2			1	11		3	24
	3.5%	0.6%	13.3%	6.0%	0.4%			0.4%	0.4%		2.3%	3.5%
	χ^2		p		χ^2		p		χ^2		p	
Neo-MMIA	12.410		0.000		0.106		0.745		10.436		0.001	
MMIA - Palatial	3.417		0.065		0.107		0.743		0.476		0.490	
EMI-III-Palatial	7.863		0.005		0.165		0.685		14.338		0.000	
Neo-Palatial	5.500		0.019		0.000		0.990		57.439		0.000	
	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial
Uncut/other cut	5936	304	172	632	2456	195	166	937	9980	1194	411	2562
	95.3%	97.4%	85.4%	89.9%	95.2%	94.2%	86.5%	84.3%	96.6%	93.9%	91.5%	88.2%
Dismembering	290	8	29	71	125	12	26	174	349	77	38	342
	4.7%	2.6%	14.6%	10.1%	4.8%	5.8%	13.5%	15.7%	3.4%	6.1%	8.5%	11.8%
	χ^2		p		χ^2		p		χ^2		p	
Neo – EMI-III	2.994		0.084		0.373		0.541		22.968		0.000	
EMI-III – MMIA	25.710		0.000		6.993		0.008		3.076		0.079	
MMIA - Palatial	2.976		0.084		0.566		0.452		4.294		0.039	
Neo-MMIA	39.401		0.000		26.262		0.000		32.133		0.000	
Neo-Palatial	37.876		0.000		122.135		0.000		323.015		0.000	
	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial	Neolithic	EMI-III	MMIA	Palatial
Uncut/other cut	4546	219	127	375	2427	245	181	962	10758	1750	500	2617
	99.2%	98.6%	94.1%	95.7%	99.2%	98.0%	95.8%	93.8%	99.1%	99.4%	96.5%	92.9%
Filleting	38	3	8	17	19	5	8	64	103	10	18	199
	0.8%	1.4%	5.9%	4.3%	0.8%	2.0%	4.2%	6.2%	0.9%	0.6%	3.5%	7.1%
	χ^2		p		χ^2		p		χ^2		p	
Neo – EMI-III	0.683		0.409		3.847		0.050		2.467		0.116	
EMI-III - MMIA	5.882		0.015		1.867		0.172		27.852		0.000	
MMIA - Palatial	0.552		0.457		1.151		0.283		9.276		0.002	
Neo-MMIA	35.294		0.000		20.662		0.000		30.000		0.000	
Neo-Palatial	40.803		0.000		92.381		0.000		387.677		0.000	

Analysis of butchery in relation to placement on the skeleton yielded limited information for skinning of the medium-sized MDT, as partial recovery led to severe losses of phalanges. The clearest pattern observed was a temporal contrast, between the Neolithic and Palatial periods, reflected in the less meticulous processing of cattle carcasses during the latter, which again contrasts with the availability of more precise tools available in this period. In the case of pigs and sheep/goats, the rarity of skinning marks combined with the rarity of recovered phalanges may indicate removal of the skin with the (now lost) phalanges attached.

Frequency and distribution of dismembering and filleting marks also differ between Neolithic and Palatial sub-assemblages, for all MDT. In the Palatial period, carcasses of all MDT appear to have been more frequently and intensively sectioned and filleted. The EMI-III pattern resembles more closely that of the Neolithic and the MMIA that of the Palatial, although it is not very safe to attribute great significance to such small samples. Interestingly, the larger-bodied cattle do not appear to have been significantly more intensively sectioned or filleted than sheep/goats and pigs in any period.

The 'elbow' joint, chosen for a more detailed analysis of butchery mark location, showed a distinct difference between Palatial and Neolithic butchery methods, most economically related to tool morphology. A particular type of cuts inflicted very distally suggested a distinct butchery practice for pigs and sheep/goats, although this may be simply a reflection of the rarity and high levels of fragmentation of cattle remains identified in Chapter 5 and further explored below.

6.4 Exploitation of within-bone nutrients

A further stage in the exploitation of animal carcasses takes the form of extraction of marrow and bone fat. Results from previous analyses suggested that such a practice may have been common at Knossos, especially for cattle, while it was noted that butchery marks, with the exception of chopping marks which are very period-specific, are not appropriate for exploring such a practice. Thus, marrow and bone fat extraction are primarily explored here through fragmentation patterns, following the observations in Binford's actualistic studies among the Nunamiut (Binford 1981: 171-77, and figs 4: 52-55). Additional evidence, more specific to the assemblage under study, is also presented.

6.4.1 Fragmentation patterns

6.4.1.1 *Methods of analysis*

This stage of analysis uses fragmentation patterns to explore in more detail the evidence for bone processing with the aim of accessing within-bone nutrients, a practice widely documented ethnographically. There are two basic strategies for accessing marrow and fats stored in bone. Bone may be fractured and marrow poured, scooped or poked out, often after preliminary heating to soften the marrow and/or render the bone more brittle (Binford 1981: 148). Alternatively, bone may be boiled to extract both marrow and fats, often after more or less intensive fracturing of the bone. The availability of such nutrients depends on the size of the animal (taxon- and age-related) and its nutritional status. Thus, it would be expected that bones of the larger and older animals would be the most cost-effective to process with this aim in

mind. Especially in the case of marrow, long bones would be those preferentially targeted. Thus, long bones of the larger cattle and the older animals of all MDT are expected to be most fragmented, which also runs counter to fragmentation expected from post-depositional processes (trampling and scavenger attrition).

The following analysis is informed by the above observations. It centres on long bones, whose fragmentation types are more readily interpreted (as opposed to flat bones like scapula and pelvis where pre- and post-depositional fracturing are difficult to differentiate). It compares the different MDT in terms of: first, the frequency of complete vs. fragmented long bones (old breaks only); secondly, the frequency of two types of long bone fragments, articular ends (typical products of fracturing for marrow extraction) and cylinders (typical products of carnivore scavenging); thirdly, the frequency of broken bones in older and younger animals (as represented by fused and unfused articular ends of long bones).

Evans1 material is excluded from this analysis due to post-excavation fragmentation and selective retention. Analysis is also informed by the conclusions drawn in the previous sections of the present chapter, on the frequency and types of butchery observed in different sub-phases. Thus, chronological groupings are different to those employed in Chapter 5, where fragmentation patterns were explored with the aim of shedding light on the severity of scavenger attrition. Finally, where samples allow, spatial analysis is also undertaken.

6.4.1.2 *Complete vs. fragmented long bones*

Already in Chapter 5 it was observed that cattle bones in all sub-assemblages were more fragmented than those of the other MDT, irrespective of levels of gnawing, and it was tentatively suggested that causes should be sought in pre-depositional processes.

Indeed, Table 6:12 shows that complete long bones of cattle are considerably rarer than those of pigs in all sub-phases; they are also considerably more infrequent than those of sheep/goats in the only slightly scavenged Palatial contexts (the Aceramic-ENIa sub-assemblages, also very infrequently gnawed, are unfortunately too small for meaningful comparison); finally, they are as frequent as those of sheep/goats in more severely gnawed assemblages (most of Neolithic and EM).

Table 6:12 Frequencies of whole and fragmented long bones by taxon and period (MaxAU; MDT only; excluding foetal/neonatal bones, unfused epiphyses, fresh breaks, worked bone and Evans1 material).

		MaxAU			% MaxAU		
		Cattle	Pig	Sheep/Goat	Cattle	Pig	Sheep/Goat
Aceramic-ENIa	Whole	0	3	2	0.0%	8.3%	0.7%
	Old	12	33	299	100.0%	91.7%	99.3%
	Total	12	36	301			
ENIb	Whole	3	8	17	3.30%	20.0%	5.4%
	Old	87	32	298	96.7%	80.0%	94.6%
	Total	90	40	315			
ENIc-II	Whole	21	9	42	4.7%	10.2%	5.5%
	Old	425	79	718	95.7%	89.8%	94.5%
	Total	446	88	760			
EN/MN Trans & MN	Whole	11	24	99	2.2%	13.8%	10.0%
	Old	489	150	888	97.8%	86.2%	90.0%
	Total	500	174	987			
LN	Whole	27	40	54	5.3%	18.9%	6.0%
	Old	482	172	853	94.7%	81.1%	94.0%
	Total	509	212	907			
All Neolithic	Whole	62	84	214	4.0%	15.3%	6.5%
	Old	1495	466	3056	96.0%	84.7%	93.5%
	Total	1557	550	3270			
EMI-III	Whole		12	22	0.0%	7.5%	1.7%
	Old	180	148	1268	100.0%	92.5%	98.3%
	Total	180	160	1290			
MMIA	Whole	2	18	9	1.9%	17.3%	2.5%
	Old	104	86	356	98.1%	82.7%	97.5%
	Total	106	104	365			
Palatial	Whole	6	138	242	1.8%	20.9%	11.9%
	Old	331	523	1790	98.2%	79.1%	88.1%
	Total	337	661	2032			

Overall, the significantly higher levels of fragmentation of cattle in the Neolithic and three BA sub-phases are suggestive of human processing. Against this background, a hoard of cattle metapodials in Stratum IIIb, in trench XY, is of particular interest. Here in a single context, seven complete metacarpals (plus three freshly broken) and one complete metatarsal (plus two freshly broken) were found together with a matching cattle radius and ulna (J.D. Evans 1964 plate 36, 2). Given how infrequent whole cattle metapodials are in the assemblage as a whole (this group alone represents more than one third of complete cattle metapodials recovered from Neolithic contexts), it is tempting to suggest that these bones were collected for marrow cracking and/or working, but that the intended processing was not carried out.

There is, however, one important parameter to consider in the comparison between taxa of different size. Hand collection in the trench tends to favour retrieval of fragmentary specimens of cattle more than those of the smaller sheep/goats, thus deflating the frequency of complete bones in the case of the former and inflating them in the case of the latter. Moreover, contrasting methods of recovery – the systematic collection of all or part of the Aceramic-ENII material (wet and dry-sieving as well as very careful collection in the trench), as opposed to partial hand collection in the trench for all subsequent sub-phases – mean that direct comparison between phases is not possible, when using all 'old' fragment types. For this reason, the next section compares complete and broken bones excluding those types of fragments most likely to be affected by differential recovery (i.e. end and shaft splinters). A comparison is then made of different fragment types, in order to explore how far breakage is related to scavenger gnawing as opposed to human processing.

6.4.1.3 *Frequencies of different fragment types*

First, the frequency of complete long bones is compared with that of broken specimens of long bones that include whole articular ends for all MDT. Because of small sample sizes, all Neolithic sub-phases are combined, while MMIA is grouped with Palatial material, given the similarities observed in frequency of butchery marks between the two groups. The data and results of statistical tests are presented in Table 6:13.

Table 6:13 Frequencies of long bone ends and whole specimens by taxon and period (MaxAU; MDT only; excluding foetal/neonatal specimens, unfused epiphyses, worked bone, shaft-only fragments and end-splinters, fresh breaks and Evans1 material).

		MaxAU			% MaxAU		
		Cattle	Pig	Sheep/Goat	Cattle	Pig	Sheep/Goat
Neolithic	Whole	62	84	214	10.0%	26.9%	14.4%
	End & shaft	555	228	1267	90.0%	73.1%	85.6%
		617	312	1481			
EMI-III	Whole	0	12	22	0.0%	18.8%	5.1%
	End & shaft	38	52	408	100%	81.3%	94.9%
		38	64	430			
MMIA-Palatial	Whole	8	156	251	8.3%	28.5%	16.0%
	End & shaft)	88	391	1322	91.7%	71.5%	84.0%
		96	547	1573			

		Cattle vs sheep/goat		Cattle vs pig	
		χ^2	p	χ^2	p
	Neolithic	7.384	0.007	44.545	0.000
	EMI-III	2.040	0.153	8.075	0.004
	MMIA-Palatial	4.011	0.045	17.514	0.000

The differential fragmentation between taxa does not appear to be an effect of differential recovery: there are statistically highly significant differences between cattle and pigs in all three sub-phases and between cattle and sheep/goats in the Neolithic, and a significant difference between the latter two taxa in the MMIA-Palatial group. The lack of a significant value when comparing cattle and sheep/goats in EM contexts is most probably a result of the small samples involved, but the difference is still in the same direction (i.e. there are no complete cattle long bones, compared to 5.1% complete sheep/goat long bones).

Secondly, frequency of end and shaft specimens (typical of marrow extraction) is compared to cylinders (characteristic of gnawing) in Table 6:14.

Table 6:14 Frequencies of long bone ends and cylinders by taxon and period (MaxAU; MDT only; excluding foetal/neonatal specimens, unfused epiphyses, worked bone, end- and shaft-splinters, fresh breaks and Evans1 material).

		Cattle	Pig	Sheep/Goat	Cattle	Pig	Sheep/Goat
Neolithic	End & shaft	555	228	1267	88.4%	79.2%	65.4%
	Cylinder	73	60	671	11.6%	20.8%	34.6%
	Total	628	288	1938			
EMI-III	End & shaft	38	52	408	90.5%	61.2%	57.3%
	Cylinder	4	33	304	9.5%	38.8%	42.7%
	Total	42	85	712			
MMIA-Palatial	End & shaft	88	391	1322	89.8%	87.1%	81.7%
	Cylinder	10	58	297	10.2%	12.9%	18.3%
	Total	98	449	1619			

		Cattle vs sheep/goat		Cattle vs pig	
		χ^2	p	χ^2	p
	Neolithic	121.863	0.000	13.492	0.000
	EMI-III	18.063	0.000	11.688	0.000
	MMIA-Palatial	4.171	0.041	0.544	0.461

Long bone ends, characteristic of human breakage for marrow extraction, are throughout far more abundant than long bone cylinders, characteristic of attrition by scavengers, and the predominance of ends is most marked in the case of cattle (highly significantly so for Neolithic and EMI-III). This suggests that fragmentation is indeed primarily a reflection of human processing, especially in the case of cattle. Fragmentation of sheep/goats and, to a lesser extent, pigs is more affected by scavenger attrition, with the exception of MMIA-Palatial pigs, where scavenger attrition was shown to have played a minor role in the formation of the assemblage. This reinforces the conclusion of the previous section, that in the sub-phases most affected by scavenger attrition (Neolithic and EMI) cattle bones were more heavily fragmented than those of pigs and sheep/goats as a result of pre-depositional human processing, and that the pattern is not a reflection of differential recovery methods or more intensive gnawing of cattle bones by scavengers.

6.4.1.4 *Age-related fragmentation patterns*

Finally, fragmentation patterns are explored in terms of broad age groups for each taxon, i.e. immature (unfused) specimens vs. mature (fused) ones. It should be noted that different anatomical parts fuse at different ages, but sample sizes are not large enough for more precise age groups to be used in this analysis. In practice, however, the use of these two broad age groups is more likely to obscure than exaggerate any age-related patterns of fragmentation. Results are presented in Table 6:15.

Table 6:15 Frequencies of whole and fragmented long bones by fusion state, taxon and period (MinAU; MDT only; excluding foetal/neonatal specimens, worked bone, fresh breaks, unfused epiphyses and Evans1 material).

		Cattle				Pig				Sheep/Goat			
		Fused	Unfused	Fused	Unfused	Fused	Unfused	Fused	Unfused	Fused	Unfused	Fused	Unfused
Neolithic	Whole	27	17	4.5%	6.6%	7	39	6.8%	25.8%	58	124	5.6%	20.9%
	Old	574	241	95.5%	93.4%	96	112	93.2%	74.2%	978	470	94.4%	79.1%
		601	258			103	151			1036	594		
EMI-III	Whole	0	0	0.0%	0.0%	2	4	5.6%	16.7%	15	3	3.4%	4.2%
	Old	71	19	100.0%	100.0%	34	20	94.4%	83.3%	425	69	96.6	95.8%
		71	19			36	24			440	72		
MMIA-Palatial	Whole	4	0	2.3%	0.0%	26	61	15.3%	23.3%	85	85	9.1%	19.1%
	Old	168	44	97.7%	100.0%	138	201	84.7%	76.7%	848	359	90.9%	80.9%
		172	44			164	262			933	444		
		χ^2		p		χ^2		p		χ^2		p	
Neolithic		1.633		0.201		14.955		0.000		88.832		0.000	
EMI-III		-		-		1.975		0.160		0.105		0.746	
MMIA-Palatial		1.043		0.307		3.959		0.047		27.988		0.000	

Overall, unfused long bones of all three taxa are more likely to survive intact than fused ones. The pattern is statistically (highly) significant for all MDT in the Neolithic and for pig and sheep/goat in MMIA-Palatial. In EM samples are very small for pig and cattle, while the low frequency of complete bones (fused and unfused) for sheep/goat may reflect the very high levels of scavenger attrition. In the case of MMIA-Palatial cattle, scavenger attrition is modest, but the sample of unfused bones is very small. Given that unfused bones are more vulnerable than fused ones to post-depositional fragmentation, the observed pattern indicates that the bones of mature animals were selectively broken open for extraction of marrow.

The first observation is that in some cases samples are small and comparison is not possible for all taxa and all sub-phases. The problem is most acute for EM material, as complete bones preserving fusion information are either absent (cattle) or rare (pigs and sheep/goats), and MMIA-Palatial cattle remains. In the Neolithic, all three taxa show a higher frequency of whole long bones among unfused than fused material. The difference is most marked in pigs and

sheep/goat (highly significant) and less so (significant) in cattle. Similarly, MMIA-Palatial unfused long bones of pigs and sheep/goats are more likely to survive intact. Despite small sample sizes, EM material shows a similar picture. It is more difficult to draw conclusions about the effect of fragmentation on cattle of different ages, with the exception of the Neolithic as already mentioned, but the difference seems less marked than in the case of pigs and sheep/goats.

6.4.1.5 *Conclusion*

The above analysis shows that fragmentation of long bones in order to extract within-bone nutrients is plausibly inferred from the available data for all periods studied. Moreover, the predicted patterns of higher intensity of fragmentation of the larger and older animals are also evident: cattle are most likely to have their long bones fragmented, pigs less so and sheep/goats least, while fused specimens are more likely to be broken open than unfused.

Spatial analysis of fragmentation data was attempted for the following three cases: EMII WCH and RRN; MN and LN CC and WC; and ENIb-ENII CC and WC; the first two cases were selected because they are represented by relatively large samples, and the last because of the observed difference in frequency of gnawing which was interpreted as a result of spatial organisation of behaviour. Unfortunately, the samples so selected are inadequate for reliable conclusions to be drawn, and so results are not presented here.

6.4.2 Further evidence for cattle bone processing

The more intensive exploitation of cattle carcasses, as evidenced by fragmentation patterns may also be inferred in the case of Neolithic sub-assemblages by an unusual type of processing of first phalanges (a single case on a second phalanx of LN date was also identified). This involves the perforation of the anterior shaft and less often the posterior shaft as well; in the latter case, a hole is formed through the bone (Figure 6:24). The earliest occurrence is in an ENIb context (Stratum VII) and the latest examples date to LN/FN. One specimen may provide an insight into the method employed, representing an early stage of the process: a first phalanx which has had slivers of the mid-shaft removed, plausibly in order to weaken the bone and allow a hole to be punched through (Figure 6:24 fourth from left). The reason for believing that the holes were made in the process of marrow extraction, rather than for creating some sort of artefact – J.D. Evans suggested a possible use as whistles (J.D. Evans 1964: 236) – is the occurrence of examples with holes only through the anterior face of the bone. While this may seem an unduly laborious method to access marrow, and unlike those employed for long bones, it is likely that it was imposed by the size and robustness of the particular element. This practice is possibly

related to the greater frequency of skinning marks on second, rather than first phalanges observed in Neolithic contexts (Table 6:7); skinning down to the second phalanx will have facilitated processing of the first phalanx, although the fact that most first phalanges were unprocessed, suggests that the primary goal of Neolithic skinning practices was to retrieve slightly more of the hide, rather than to ensure that first phalanges were available for marrow extraction. It is also possible that the holes reflect consumption straight from the bone rather than after cooking in a pot, as may have been the case with other cracked bone.

If the above interpretation of pierced phalanges is correct, it again implies a fairly intensive exploitation of the carcasses of cattle. Five examples of cattle phalanges split longitudinally presumably represent an alternative strategy for marrow extraction. Unfortunately, the numbers of retrieved phalanges of sheep/goat and pig are too few to determine whether cattle phalanges (like cattle long bones) were more thoroughly processed than those of the other MDT. From the Evans2 Aceramic deposits, however, which high standards of retrieval and also low levels of scavenger attrition, phalanges of sheep/goat were broken open for marrow extraction.

6.4.3 Chopping for marrow extraction

Although rare, an unusual type of chopping is observed in BA – and most commonly in Palatial assemblages – occurring on a range of long bones of all MDT. It involves chopping through the shaft and would have thus exposed marrow (Figure 6:25c). It is not likely that such chops would have been randomly inflicted in the process of dismembering, as there exist a number of chop marks, which are precisely inflicted to cut through the articulation (Figure 6:25a&b). It is suggested that such cuts were made with the purpose of exposing the marrow cavity, either before or after cooking. In the first case, more flavour would have been added, while in the second, it would have been possible to consume not only the meat but also the marrow.

6.5 Multiple transverse knife cuts: evidence for culinary elaboration?

A distinctive type of knife cut was observed on a number of the meat-bearing long bones, i.e. humerus, radius, femur and tibia, of sheep/goats and pigs. These are multiple transverse marks occurring at more or less regular intervals along the shaft of these elements, occasionally around all its aspects (Figure 6:26). Thirty-five specimens bore such marks, although it is possible that further examples were undetected, as they could only be identified on specimens preserving a substantial part of the shaft. The earliest example was found in a Protopalatial context, and a single example was identified in a Final Palatial deposit. Most examples derive from

Neopalatial deposits, probably an effect of the larger sample size available from this phase. They occur in both the RR and HH, and therefore are not spatially restricted.

In the preceding analysis, these marks were categorised as filleting marks, as they are obviously aimed at sectioning the muscle around the bone. They are not, however, 'classic' filleting marks, inflicted in the course of the removal of meat from the bone, as, in order to achieve stripping of the meat, longitudinal cuts would also have been necessary to free up the muscle (Binford 1981: 128). A supporting argument is that they were observed only on bones of pigs and sheep/goats and not the larger cattle, meat joints of which could easily have been cooked 'on the bone' given the availability of suitable cooking vessels (i.e. tripod cooking pots) in the periods concerned. It is tempting to suggest that these cuts reflect a particular type of preparation of joints (there are at least two examples which also bear chopping marks inflicted in the process of dismembering, see area indicated with an arrow in Figure 6:26). This regular cutting at close intervals may have been intended to reduce cooking time or may have been related to etiquette - creating portions easily removed with the fingers (without use of cutting implements in serving or consumption), or ensuring equal portions for participants.

6.6 Taxonomic composition

6.6.1 MDT frequency by sub-phase

Further information on consumption practices can also be gleaned from the analysis of the relative frequency of the four MDT in each sub-phase. In order to control for the worst effects of recovery and scavenger attrition biases, as identified in Chapter 5, the following sets of data are excluded from the calculations:

- Phalanges 1-3, calcanea and astragali of all MDT, under-represented in medium-sized MDT because of low retrieval and greater vulnerability to scavenger attrition;
- Mandibles/mandibular teeth and horncores, because cattle skulls appear to have been differentially discarded in the Palatial period, because LN sheep/goat mandibles may be over-represented in the present assemblage, as a result of previous analysis, and because horncores are absent in pigs and also are very poorly preserved in sheep.

MinAU counts are used which best control for differential fragmentation between body parts and taxa. All datasets, apart from ENIa, are well above the threshold for a statistically valid sample. The results are tabulated in Table 6:16 and presented as a line chart in Figure 6:27. Specimens not identified beyond the sheep/goat level have been proportionately attributed to

these two species in Figure 6:27; with the exception of Old Palace, Final Palace and especially ENIa, there are adequate samples of specimens identified to the level of sheep and goat from each sub-phase.

Sheep are the predominant taxon throughout, while pigs and goats are each more or less steadily represented at ca. 10-25% of the total. Cattle show the greatest fluctuation, being the least abundant taxon in earlier Neolithic and BA and the second most frequently recovered taxon in ENIc-LN contexts. Fluctuations of sheep and cattle appear to mirror each other inversely (i.e. where sheep decrease, cattle increase, and *vice versa*). Finally, frequencies of the four MDT converge in the Palatial period.

Table 6:16 Frequencies of MDT and gnawing by sub-phase
(MDT: MinAU; excluding phalanges, calcanea, astragali, mandibles/mandibular teeth, horncores; %MinAU for sheep and goats includes sheep/goat assigned in same proportions as specimens identified to species. Gnawing frequency: MaxAU; excluding loose teeth).

MinAU	Cattle	Pig	Sheep	Goat	Sheep/Goat		Total
					Prop Sheep	Prop Goat	
Aceramic	18	90	189	59	167	52	575
ENIa	22	43	106	21	58	12	262
ENIb	213	198	409	76	326	61	1283
ENIc-ENII	767	239	516	148	648	186	2504
MN	1056	375	787	377	539	258	3392
LN	1751	1123	1655	765	1075	497	6866
EMI-EMIII	230	232	504	186	616	228	1996
MMIA	123	160	195	101	103	53	735
OP	56	116	131	78	93	55	529
NP	271	757	735	558	391	297	3009
FP	82	124	98	65	61	41	471

% MinAU	Cattle	Pig	Sheep (with prop.attrib.)	Goat (with prop.attrib.)	Frequency of gnawing
Aceramic	3.1	15.7	61.9	19.3	11%
ENIa	8.4	16.4	62.8	12.4	19%
ENIb	16.6	15.4	57.3	10.7	35%
ENIc-ENII	30.6	9.5	46.5	13.3	31%
MN	31.1	11.1	39.1	18.7	24%
LN	25.5	16.4	39.8	18.4	22%
EMI-EMIII	11.5	11.6	56.1	20.7	26%
MMIA	16.7	21.8	40.5	21.0	19%
OP	10.6	21.9	42.3	25.2	9%
NP	9.0	25.2	37.4	28.4	8%
FP	17.4	26.3	33.8	22.4	14%

As discussed in Chapter 5, the earlier Neolithic deposits were partially sieved, while material from later periods is essentially all retrieved in the trench by hand. In light of this, one would expect all medium-sized MDT to show a decline from the partially sieved Aceramic-ENII to unsieved MN-FP sub-phases. Similarly, medium-sized MDT might be expected to decline from Aceramic to ENII in the face of increasing scavenger attrition, and then to recover somewhat in MN and more sharply in the Palatial period, as attrition diminishes dramatically. In broad terms,

the changing proportions of cattle and sheep seem to mirror these variations in recovery and attrition, suggesting that the exclusion of cranial and small limb bones has only partly controlled for the predicted biases. On closer inspection, however, it is clear that the trends in taxonomic composition are not artefacts of variable recovery and survival.

First, from Aceramic to ENIb, the increase in cattle remains is mainly at the expense of goats, but from ENIb to ENIc-ENII it is at the expense of sheep and pigs. If the increase in cattle was simply an artefact of preferential retrieval and survival, this should have affected the three medium-sized MDT in a more or less consistent fashion. Secondly, from ENIc-ENII to LN, the proportion of cattle remains fairly stable, despite a decline in the frequency of gnawing. At the same time, sheep decline in favour of goats and pigs, again suggesting that real shifts in consumption patterns are over-riding any taphonomic biases. Thirdly, from LN to EMI-III, sheep increase sharply at the expense of cattle, despite unchanged recovery methods and a slight increase in attrition. Finally, in the Palatial period, when the level of attrition is low, the frequency of cattle is close to its EMI-III level and the principal trend observed is a decline of sheep in favour of goats.

Despite problems of variable survival and recovery, therefore, it seems clear that the four MDT exhibit substantial changes in frequency of consumption, or at least deposition, in the excavated parts of Knossos. During the Neolithic, frequency of consumption of sheep declines from ENIc onwards, offset by a fairly substantial increase in the consumption of cattle, pigs and goats. In the BA, there is a peak in consumption of sheep in EM, with a decrease of cattle and pigs. From MMIA onwards the picture changes rather dramatically, culminating in relatively balanced frequency of consumption of all four MDT in FP. The implications of these observations will be discussed in Chapter 8, but at this point it should be noted that the increase in consumption of cattle during the Neolithic, suggested by Broodbank, appears to be valid and not an artefact of taphonomic distortion as argued by Winder and Whitelaw (Chapter 3).

6.6.2 The consumption of rare taxa

As already mentioned (section 6.3.1), there is evidence – in the form of butchery marks and parts of the skeleton present – to suggest that some of the non-MDT identified were consumed at least in certain sub-phases, although their rarity suggests that they did not contribute considerably to the diet of the inhabitants. While it is no surprise that deer (red and fallow), hare and equid were consumed, butchery marks also suggest the consumption of two carnivores, dog and badger. Table 6:17 lists the frequency of butchery marks for each taxon and Table 6:18 the types of marks and the body parts on which they occur.

Table 6:17 Frequency of cut, chop and saw marks in rare taxa by period (MaxAU).

	Neolithic							Bronze Age						
	Cut		Chop		Saw		Total	Cut		Chop		Saw		Total
	MaxAU	%	MaxAU	%	MaxAU	%		MaxAU	%	MaxAU	%	MaxAU	%	
Equid	1	100.0%	-	-	-	-	1	-	-	-	-	-	-	2
Dog	3	3.1%	-	-	-	-	97	6	14.6%	-	-	-	-	41
Hare	-	-	-	-	-	-	1	1	100.0%	-	-	-	-	1
Badger	3	3.6%	-	-	-	-	84		0.0%	-	-	-	-	7
Fallow deer	-	-	-	-	-	-	2	5	26.3%	-	-	-	-	19

Table 6:18Anatomical distribution of butchery marks and bone working in rare taxa by sub-phase (MaxAU).

			SC	Hd	Rp	U	MCp	PE	Fp	Fd	Td	MTp
Dog	ENIb	Dismembering						1				
		Worked				1						
	ENIc-ENII	Dismembering	1									
		Worked				1						
	MN	Diem & Fillet					1					
	Old Palatial	Dismembering				1						
	Neopalatial	Dismembering	1						2			1
	Final Palatial	Dismembering						1				
Badger	MN	Dismembering		1								
	LN	Dismembering			1						1	
Hare	Final Palatial	Filleting						1				
Fallow deer	Neopalatial	Dismembering		2	1				1	1		
Equid	LN	Dismembering						1				

The following conclusions can be drawn from the data. First, the overwhelming majority of marks can be categorised as dismembering, with two instances of filleting, of meaty parts of the skeleton, while skinning marks appear to be absent. The latter observation may not be so meaningful, since skinning may have been practiced on the rarely recovered phalanges of the smaller taxa (i.e. dogs, badgers, even deer), but evidently (based on the evidence of dismembering marks), even if rarely, dog and badger carcasses were sectioned in a fashion similar to that of the MDT. Another interesting observation is that dog bones were (very occasionally) used to manufacture tools in the Neolithic. Fragmentation patterns are not very reliable, mainly due to the small size of individual samples for each taxon, but in the case of deer they are compatible with consumption as there are no examples of complete bones, while ca. 40% of dog and 26% of badger long bones are complete, frequencies considerably higher than those for the MDT (Table 6:12). This could imply that most of the remains of dogs and badgers do not belong to animals consumed, as they would have been too large to cook if not sectioned in some manner.

Temporal patterning may be cautiously suggested. While dogs appear to have been consumed in both Neolithic and BA, both the considerable decrease in the frequency of skeletal remains of badger and the absence of butchery marks in remains from BA contexts may imply that these animals were no longer consumed and it is not impossible that the few remains from Palatial contexts are the result of later disturbance. On the other hand, deer remains (red and fallow) are encountered only sporadically in Neolithic contexts (as single specimens in few sub-phases), but fallow deer are a lot better represented in Neopalatial and Final Palatial contexts (being absent in the earlier BA phases) and, to judge from the parts of the skeleton found and presence of butchery marks, represent the remains of food.

For the remaining two taxa, hare and *Equus*, conclusions can only be tentative in view of the minute samples. The extreme rarity of the former may be due to post-depositional biases (partial recovery and scavenger attrition) given the small size of the animal, but these are not plausibly invoked for the rarity of *Equus*. It is striking that in the whole assemblage equids are represented by only three specimens. The LN pelvis bearing dismembering marks is of relevance in the present discussion. If the evidence is taken at face value, it implies the consumption of the meat of a very rare animal just introduced in the area, evidently with great effort, while the butchery marks are compatible with ones inflicted with a sharp metal tool. The uniqueness of the find and type of marks recommend some caution in its interpretation. It is not implausible that this is a later intrusion and direct dating may be required to resolve the conundrum.

6.7 Primary and structured deposition

There are a few instances where it is possible to identify faunal groups in a primary context of deposition. Such groups are characterised by the presence of articulating elements, matching diaphyses and epiphyses of unfused long bone ends, or a concentration of particular body parts, suggesting fast deposition and absence of subsequent disturbance. In a few cases, these groups can be attributed to particular types of activity. A detailed and systematic analysis which would allow characterisation of all deposits is not possible at this stage of research (other contextual evidence being presently unavailable), so a few examples are isolated and discussed here.

6.7.1 Neolithic

Two deposits are of interest, which contained concentrations of particular body parts. The first, in trench XY, has already been mentioned in the discussion concerning marrow processing (section 6.4.1.2). The second, AC 15e (Stratum V), contained, exclusively, sixteen cattle

astragali, some of which bore dismembering marks. A number of cattle astragali from Neolithic contexts had been modified by some grinding action, creating more or less flattened lateral and medial aspects. This modification suggests a distinctive pattern of use, whether practical (e.g., as polishers/burnishers) or otherwise (cf. later use as gaming pieces and aids to divination), and it is plausible that AC15e represents a hoard of astragali destined for a particular use, but for some reason abandoned and buried. This evidence for hoarding of bones in contexts other than culinary is relevant to the discussion of processes related to bone tool manufacture in section 6.8.1.

Other than these examples, Neolithic deposits do not contain concentrations of bone groups suggestive of quick and/or deliberate burial of material from large scale processing or consumption of animals. Articulating or matching parts of the skeleton of animals are most often limited to feet and matching unfused epiphyses and diaphyses and occur, if at all, as single examples in individual deposits. The low frequency of such articulating/matching specimens, combined with the high levels of carnivore gnawing observed in most sub-phases and the relative rarity with which bone was discarded in spatially constrained features such as pits, suggests little effort during the Neolithic to preserve or bury the remains of specific carcass processing or consumption events. The recurrent occurrence in Neolithic deposits suggests that the lack of larger articulating groups is the product, at least partly, of discard or consumption behaviour and not of post-discard taphonomic processes.

6.7.2 Palatial

A different picture is revealed in Palatial deposits. Evidence for rapid burial (presence within single contexts of articulating elements and/or matching unfused epiphyses and diaphyses, low frequency of scavenger attrition) is widespread in the Palatial sub-assemblage. This common pattern is best illustrated by a specific example, a concentration of bones from a pit of LMIA date[4], cut into earlier deposits and containing a sizeable – for a single context – faunal assemblage (374 MinAU). The lowest observed frequency of carnivore gnawing, at 4% MaxAU, is compatible with the high frequency of complete long bones (9.5% pig and 15% sheep/goat) and low frequency of shaft cylinders (ca. 9% for pigs and sheep/goats). The age groups represented, based on fusion, are comparable with the remaining Palatial sub-assemblage. These characteristics are further stressed by the presence of thirteen groups of articulating elements, three of which consist of three elements each and matching unfused epiphyses (a, b), and 14 examples of matching unfused epiphyses and diaphyses, the highest

[4] There may be further such examples, not yet identified because of the lack of stratigraphic information.

concentration of such examples in any of the analysed contexts (for an example see Figure 6:28 b).

These features suggest rapid deposition and absence of subsequent disturbance. Therefore, given that the fill of Pit G did not comprise distinct multiple fills, one can plausibly infer that the faunal remains therein were deposited in a single event, soon after the processing/consumption of their meat. The articulating elements do not bear any filleting marks such as might have indicated cooking of meat off the bone. This suggests that these articulating bones may have been discarded after having been cooked, as the author observed experimentally that a similar joint remained articulated, as the connecting cartilaginous tissues around articulations remained intact even after several hours of stewing (Figure 6:28c).

In terms of the pre-discard activities represented by this deposit, taxonomic composition is not unusual: all four MDT are represented by all parts of the skeleton, i.e. skull, trunk and limb (with the exception of cattle cranial remains). The relative abundance of the four MDT, however, compared to the rest of the contemporary sub-assemblage, differs considerably (Table 6:19).

Table 6:19 Taxonomic composition of Pit G compared to other contemporary assemblages (MinAU; undifferentiated sheep/goat remains attributed to sheep and goat in same proportions as specimens identified to species).

	% MinAU		
	Pit G (N=374)	Other LMIA (N=650)	All Neopalatial (N=3503)
Cattle	2.9	13.2	11.3
Pig	23.0	24.9	24.5
Sheep	26.5	31.7	38.2
Goat	47.6	30.2	26.1

Cattle bones are a very minor component of the Pit G assemblage, while goat remains make up almost half of it. While the considerably lower frequency of cattle may in the first instance reflect the absence of taphonomic biases, which may have adversely affected medium-sized taxa in other contexts, thus inflating numbers of cattle remains, this does not explain the preponderance of goats in Pit G. On the other hand, the frequency of body parts from different parts of the skeleton is revealing. Cattle are probably represented by a single joint from the front leg (the single calcaneum might be a result of contamination), while heads and feet (metapodials and phalanges) of pigs and sheep/goats are under-represented (Figure 6:12). This suggests a temporal and possibly spatial segregation of the various stages between dressing of the carcass, cooking and consumption.

Based on the evidence presented above, Pit G probably contains the remains of a special event, where certain taxa and parts of the carcass were consumed. Finally, the unusual character of the deposit lies not least in the fact that these remains (together with a number of what seem like complete, mostly consumption vessels) were deposited in a distinct feature rather than being discarded in a refuse dump. More detailed study of the artefactual and stratigraphic context of such deposits is necessary before drawing final conclusions, but the evidence so far suggests the exceptional treatment of the remains of a special event. Further distinctive characteristics which differentiate the Neolithic from the Palatial preparation of meat are hinted at by the presence of the unusual butchery marks, while further elaboration is revealed by more frequent consumption of rare taxa (fallow deer), as discussed earlier.

6.8 The use of bone and horn as raw materials

The evidence for the exploitation of bone and horn in craft-working comes in two main forms: as finished objects and as by-products of processing. Finished objects, in particular various types of implements, are most common in Neolithic contexts. J. D. Evans reports ca. 1000 such artefacts from his first campaign and several more were identified among the faunal remains in the course of the present study. There should be at least 2000 objects in total (from both campaigns combined), providing probably one of the largest such excavated assemblages from the whole of Greece, and certainly the only one covering the whole of the Neolithic. For the purpose of the present study, only a small sample of the finished objects was studied due to time constraints[5], with the aim of exploring primarily choice of taxa, elements and age groups. A few examples of worked bone from BA contexts, such as bone plaques, were also observed, plausibly components of composite artefacts. Finally, some specimens bore tool marks of a kind suggesting their derivation from activities relating to the manufacture of the above items. The evidence and meaning of these finds is discussed further below.

6.8.1 Neolithic bone tools

The use of bones to produce *implements* is very period-specific. While large numbers of such objects were identified in Neolithic contexts, the production and use of most types ceases abruptly in EM. Only pointed objects persist into the BA and only very infrequently (the latest contexts in which such objects were identified were EMIII).

Only artefacts identified while sorting recordable specimens from bone bags were recorded (ca. 250 examples) in order to explore patterns in the range of taxa and body parts used (some

[5] A more extensive analysis of all bone artefacts will be the subject of a future study.

examples relevant to the discussion are shown in Figure 6:29). It was observed that sheep/goat limb bones were overwhelmingly used (80%) and indeed, when identification to species was possible 70% of these were shown to be sheep, compared to 14% cattle and 6% pig. Two examples of worked dog ulnas were also identified (from an ENIb and an ENIc context). In terms of age, mature specimens were most commonly used, and immature (unfused bones) rather rarely (Figure 6:29c). Body parts most commonly used are ulnae, tibiae and metapodials; radii are used rarely, while ribs are used for the manufacture of very specific types of artefacts (Figure 6:29b). Carnivore gnawing is very infrequent, especially when compared with the levels observed for the unmodified faunal assemblage.

The differences in abundance of different taxa partly reflect availability, but there is a marked tendency to prefer sheep at the expense of other taxa, which well exceeds the frequency of the species in the various sub-assemblages (Table 6:16). Bones of sheep and mature individuals may have been preferentially used for functional reasons (straightness, length and robusticity being potential prerequisites) instead of those of pigs, which were mostly culled before reaching maturity (see Chapter 7), and cattle, which were intensively fragmented in the process of extracting within-bone nutrients. The choice of specific taxa, elements and age groups, and the rarity of gnawing marks suggest that for well-formed tools (not expediently used bone), bones would have been collected and worked (or curated) soon after the slaughter/consumption of the animals, as has been suggested for Neolithic Makrygialos, Northern Greece (Isaakidou 2003).

Although a detailed discussion of the *chaîne opératoire* of bone tool manufacture at Knossos is not possible in the present study, it is worth mentioning that two specimens, bearing sawing marks, belong to taxa and parts of the skeleton used for tool manufacture: a sheep/goat proximal tibia and a sheep proximal radius (Figure 6:29e). This lends support to the classification of sawing marks in the Neolithic as a manufacturing-related process, and of these specimens as its by-products.

6.8.2 Bronze Age bone and horn-working: prestige artefacts?

Whilst the vast majority of bone artefacts in Neolithic contexts at Knossos appears to have performed some practical function – e.g., only one example of a figurine made of bone was recovered from Neolithic deposits (J.D. Evans 1964: 237) – in the BA bone appears to have been almost exclusively used in the manufacture of non-utilitarian objects. The disappearance of bone implements, from at least the MMIA onwards, is accompanied by the appearance of two other types of finds: worked sections of bone, plausibly ornamental parts of composite objects (small plaques often with holes and pegs to attach them to another surface, and regular

scratching possibly to improve adhesion on one side), and by-products of processing. In the first category belongs a 'plaque' from the shaft of a cattle tibia (Figure 6:30a) recovered from a LMIB context. Other such objects were not studied, as normally they are classed as small finds and stored separately from the faunal assemblage. In the second category belong the sawn sections of cattle long bones, already discussed in section 6.3.2.2 (Table 6:20; Figure 6:30b, c). Identical such remains, unambiguously related to craft-working, have been recovered in great quantities in Roman and medieval contexts in north-western Europe, mostly in urban sites (Figure 6:31) (e.g., MacGregor 1985). Other examples from Minoan Crete have been reported from Protopalatial contexts at Mallia (Poursat 1996: 121) and, more recently, EMII deposits at Poros, Herakleio (Isaakidou *in prep.*[a]) (Figure 6:30d&e). Finished objects are typical of Prepalatial and early Palatial funerary assemblages from other areas of Crete (e.g., Krzyskowska 1983), but not from Knossos itself, where mortuary activity is unknown from this period.

Table 6:20 Sawn specimens recovered at Knossos by body part, taxon and period (MaxAU).

		EMIII	MMIA	Neopalatial
Cattle	HC		2	3
	Rp			1
	MCd			1
	Fp		1	
Goat	HC	1		1

Horn-working is also suggested by *sawn* sections of cattle and goat horncores found exclusively in BA contexts (Table 6:20; Figure 6:30f-h)[6]. Although such remains are rare in the present assemblage (Table 6:20), their interpretation as by-products of horn-working is supported by the following arguments. The availability of cleavers suggested by chop marks on a number of specimens (section 6.3.2.2), at least from MMIA onwards, and the height at which the horncore is sectioned (often near the tip, or at various heights along its length, see Figure 6:30d-g) make it unlikely that sawing was employed in order simply to remove the horns from the skull in preparation for cooking (sawing around the *base* of the horncore would have been a more likely choice). There is additional *textual* evidence from the later Linear B documents, where specialist craftsmen and actual use of horn are referred to (see Chapter8 for further discussion).

Interestingly, two contexts, of MMIA and LMIB date each contained one sawn long bone and one sawn horncore, suggesting perhaps that these two activities took place in proximity, possibly in the same workshop. This is suggested with some caution, since the same contexts consist largely of carcass processing/consumption debris, insofar as the faunal remains are

[6] A group of nine sawn cattle horncores of Old Palatial date is now also available from Dr. C. MacDonald's excavations at the Southwest House area (Isaakidou in prep. b).

concerned, but the overall rarity of sawn specimens would suggest that this co-occurrence may be of some significance. Moreover, the area of the 'Ivory Deposit', characterised by the excavator as a workshop (Hood 1960: 24), might provide some insights into the context and associations of bone working with ivory working. As well as worked bone, the deposit contained a large number of fragments of 'ivory' (believed to be hippopotamus and/or elephant, although examination of the material by a specialist is pending), together with finished/half-finished plaques made of cattle long bone sections and several fragments of chipped 'ivory' and bone (the latter identified by myself), recovered by sieving. The archaeological significance of these observations will be discussed in Chapter 8.

6.9 Conclusions

This chapter explored the evidence for carcass processing and consumption and discard and identified a number of patterns, some of which are persistent throughout the Neolithic and the BA, and others particular to individual periods. Starting with the former, it was observed that whole carcasses of all MDT were processed on site, and no deposits were identified which suggest 'industrial' scale processing in any period. More intensive processing and extraction of nutrients (illustrated by bone smashing) concentrated on the larger and older animals (i.e. cattle bones were more intensively processed than pigs and sheep/goats, and older animals of all MDT more so than younger ones), providing a plausible explanation for the over-representation of cattle phalanges in several assemblages. There *is* under-representation of extremities of MDT in some Palatial contexts, however, which suggests that segregation of activities (i.e. initial carcass dressing and consumption) took place, at least occasionally.

Changing technology is to some extent detectable in practices of carcass processing and exploitation of raw materials. From EMI onwards, stone cutting tools are apparently abandoned, to be wholly replaced by metal tools: initially perhaps only knives, but then also saws and, possibly towards the end of EM, cleavers. Bone tools likewise seem to be abandoned during the course of EM, again presumably replaced by metal equivalents. The advent of different tool types, however, does not affect the Neolithic habit of sectioning carcasses (even of the larger cattle) into large 'parcels' starting at the shoulder and hip, as this practice persists into EM. The size of meat 'parcels' possibly changes in MMIA and certainly in the Palatial period, when carcasses of all MDT are dismembered more frequently and at all leg articulations, as well as being more frequently filleted. Similarly, saws do not seem to have been used in butchery, but only in bone processing to extract raw materials for craft-working, while cleavers were used relatively infrequently and were not used preferentially to process the larger cattle carcasses.

In principle, the introduction of metal knives and especially metal cleavers should have made butchery potentially more efficient, and so facilitated the processing of animal carcasses on an 'industrial' scale in the BA, but there is no evidence that this occurred. The only hint of anything approaching such a practice is the slightly less careful skinning practised in the case of cattle, where skinning marks are found equally frequently on first phalanges and metapodials. This contrasts with the Neolithic, when preferential skinning of cattle on second phalanges suggests greater concern to extract more of the skin, or even particular parts of the skin – possibly to preserve the natural conformation of the skin around the phalanges, in a manner similar to that practiced by the Nunamiut and described by Binford (1981: 103-4).

Changing butchery practices are most evident in MMIA-Palatial contexts, in the more intensive sectioning and filleting of carcasses, perhaps linked to cooking in pots rather than roasting (the latter being the only option for the large parcels of meat implied by butchery practices in the Neolithic-EM). This in turn may be related to other indications of increased elaboration of cuisine (the consumption of rare introduced animals, such as fallow deer) and possibly etiquette (the unusual multiple transverse knife marks).

In conclusion, there appears to be a fundamental contrast in the processing of animal carcasses and consumption of meat between the Neolithic-EM and the MMIA-Palatial periods. In the former, the consumption of some large animals (cattle; sub-adult and adult pigs, sheep and goats) and the sectioning of carcasses into large parcels imply a high-level of commensality or sharing out of meat, while the wide dispersal of skeletal remains (at least partly attributable to pre-depositional processes) suggests that meat was distributed for consumption by relatively small social groups. The evidence is compatible with, and perhaps suggestive of, sharing or reciprocal exchange of meat in a more or less egalitarian context. By contrast, in the latter period, at least some meat was apparently consumed in special events whose remains were collected and disposed of separately from other refuse. This implies the provision of meat in a larger and more public gathering that would have emphasised the asymmetry between host and guest. Additionally, preparation in the BA appears to have been elaborated through more sophisticated cuisine and the addition of meat from rare animals (cf. Davis and Bennet 1999), providing opportunities to set apart some consumption events (and those participating in them). Finally, the spatial and/or temporal segregation of slaughter/butchery and preparation/consumption (implied by dressed carcasses) will have provided further opportunities to differentiate between groups participating in different stages of the cycle of carcass reduction. The archaeological background to the above practices is explored in Chapter 8.

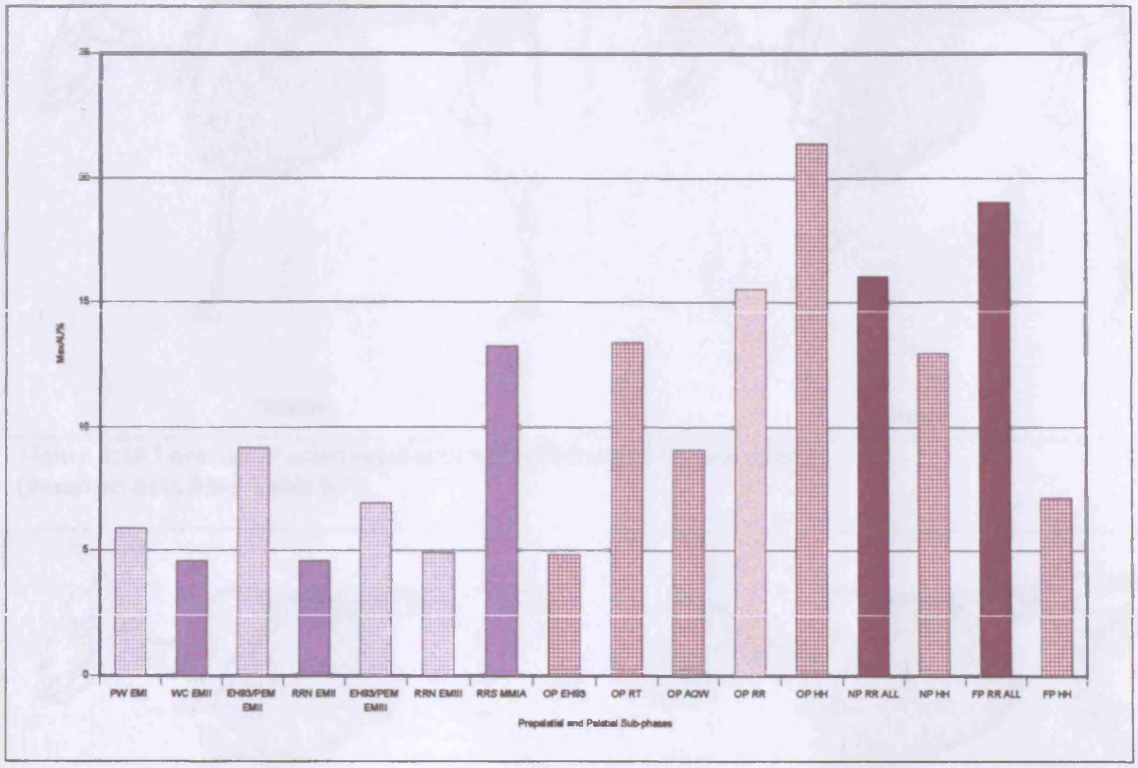


Figure 6:16 Frequencies of cut specimens by area and sub-phase of the BA (MaxAU; MDT only; excluding loose teeth, phalanges, newborn/foetal specimens; solid bars represent sub-assemblages with >400 cases, dotted bars 300-400 cases, grid-filled bars <200 cases; lilac bars: Prepalatial: purple bars: Palatial).

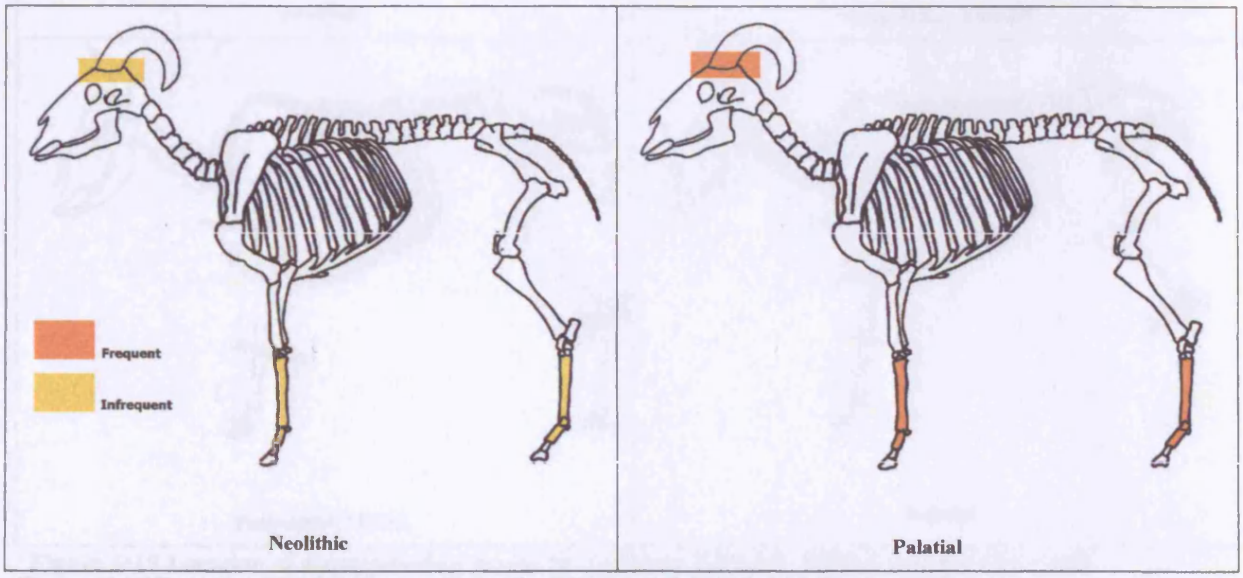


Figure 6:17 Location of skinning marks in Neolithic and Palatial sheep/goat remains (based on data from Table 6:7).

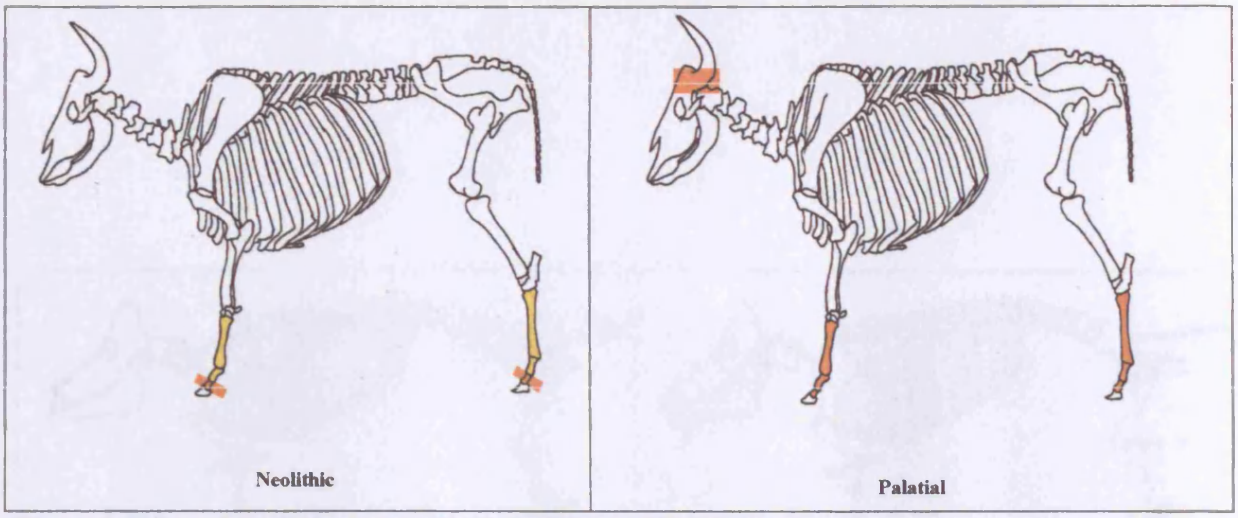


Figure 6:18 Location of skinning marks in Neolithic and Palatial cattle (based on data from Table 6:7).

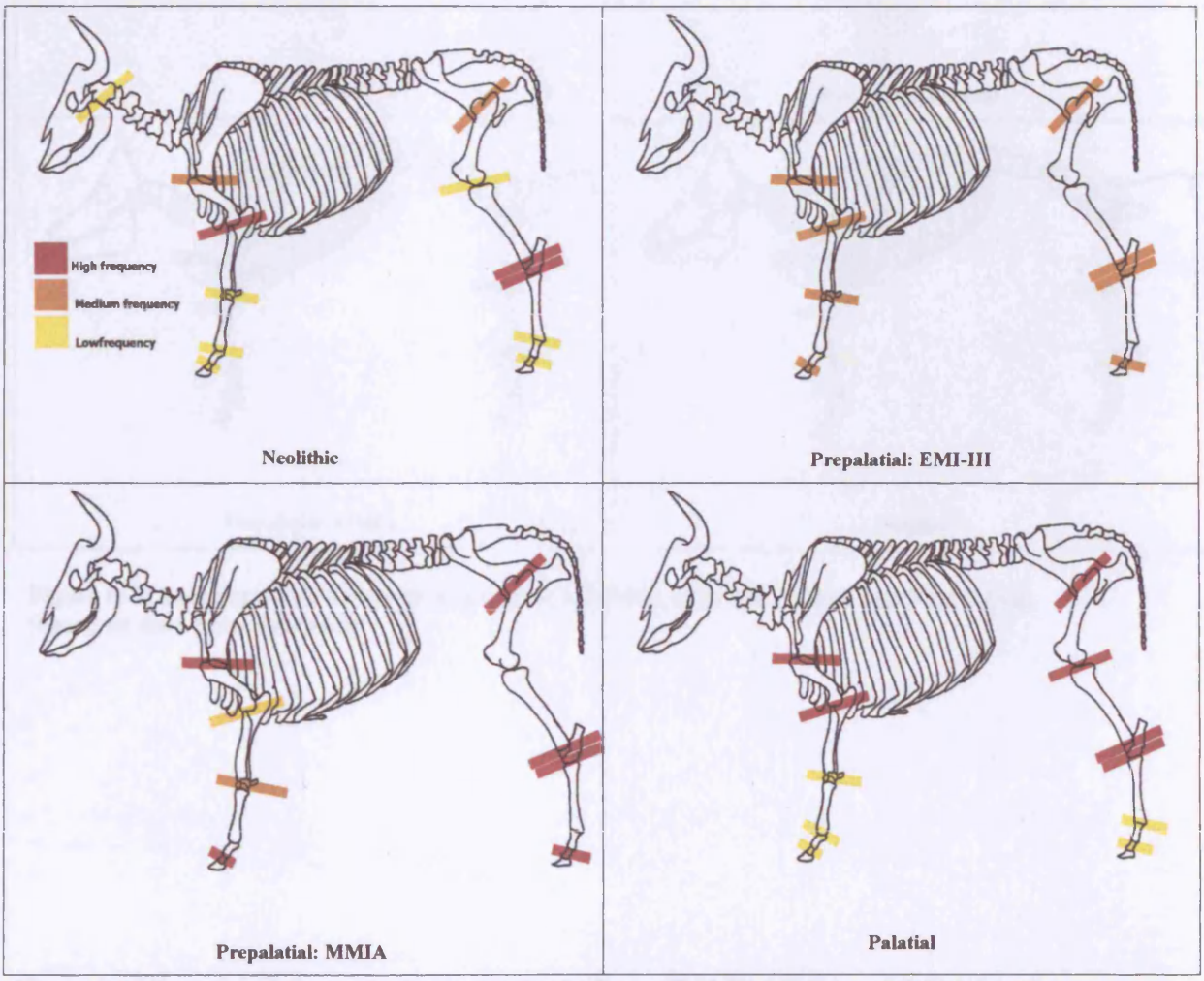


Figure 6:19 Location of dismembering marks in Neolithic, EMI-III, MMIA and Palatial cattle (based on data from Table 6:8).

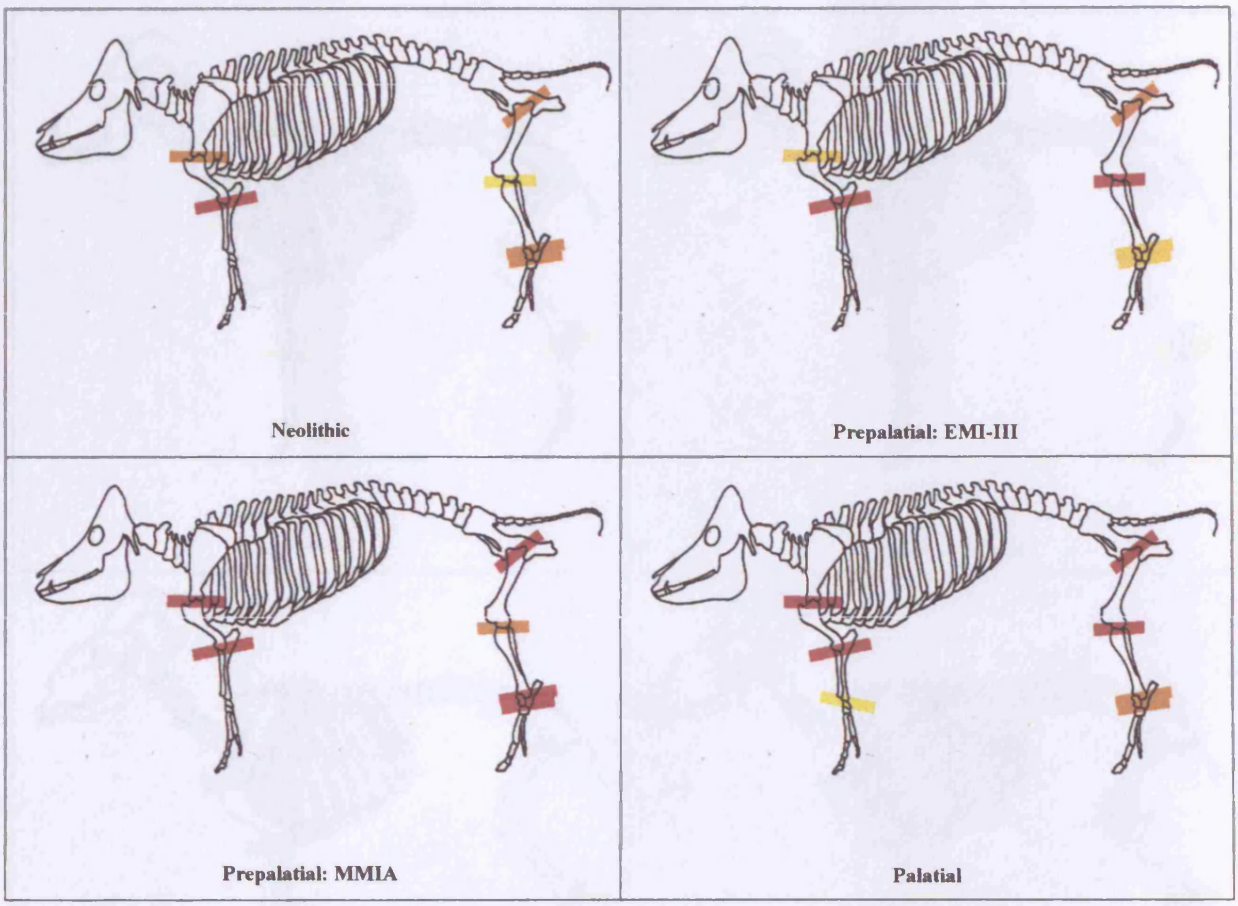


Figure 6:20 Location of dismembering marks in Neolithic, EMI-III, MMIA and Palatial pig (based on data from Table 6:8)

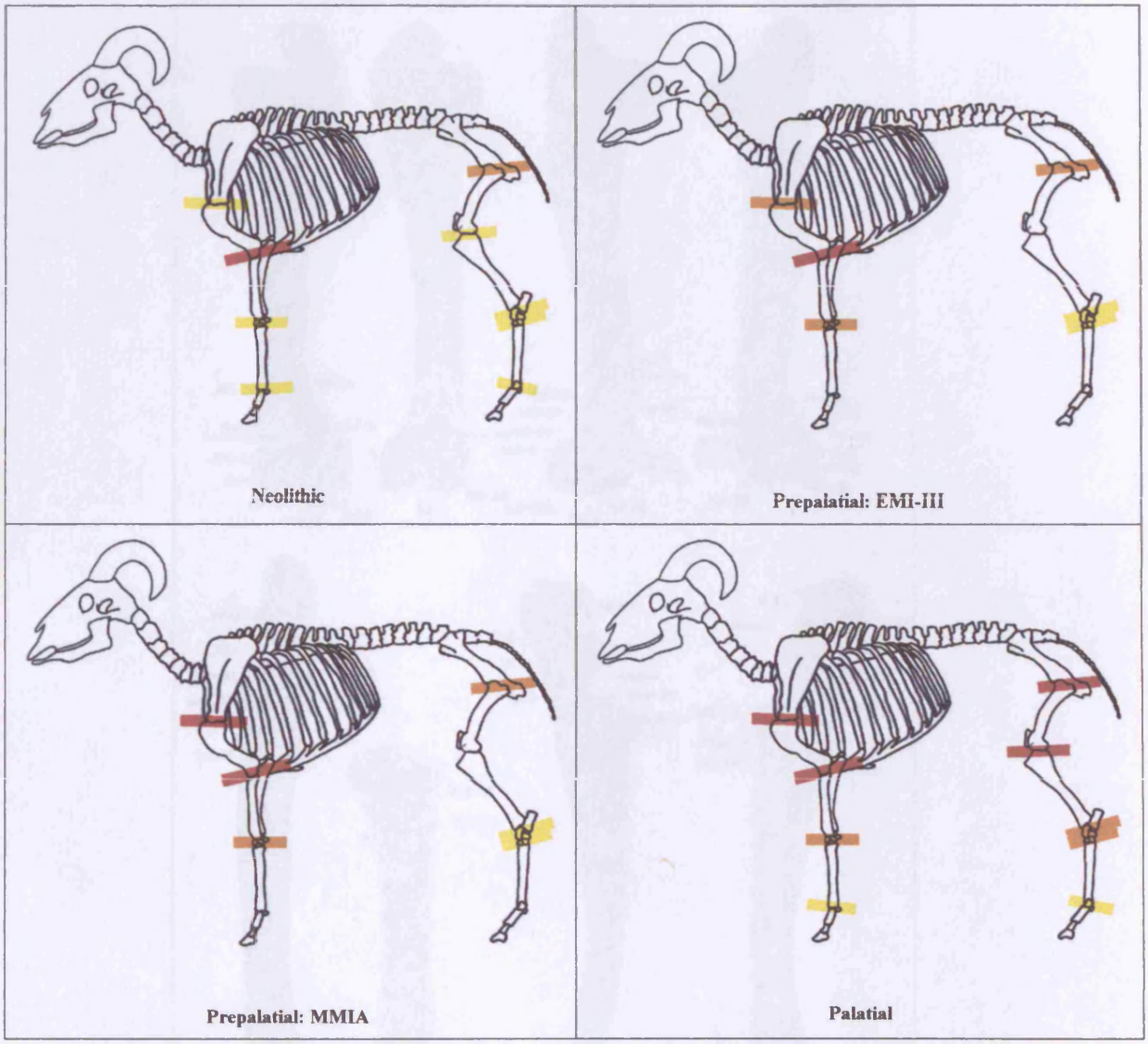


Figure 6:21 Location of dismembering marks in Neolithic, EMI-III, MMIA and Palatial sheep/goat (based on data from Table 6:8)

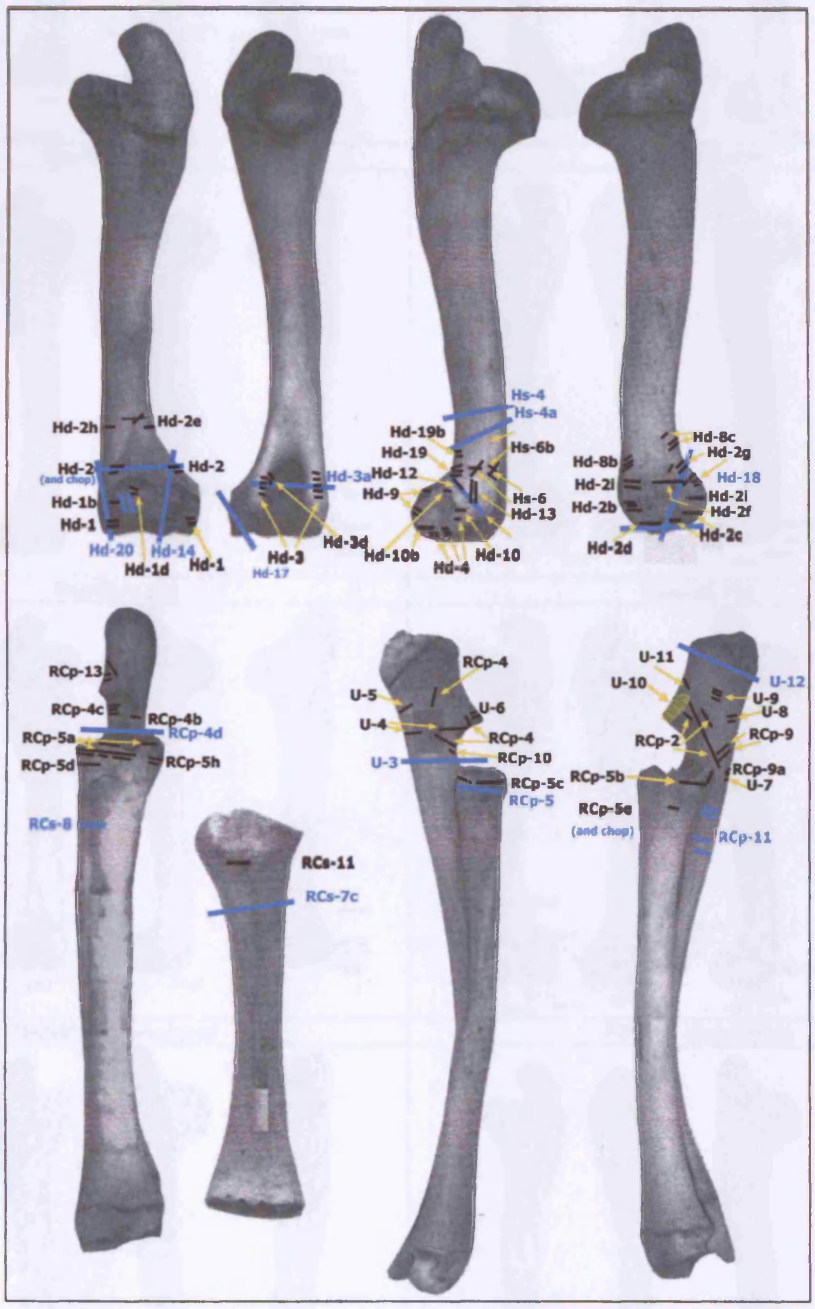


Figure 6:22 Location and codes of dismembering marks observed on elbow joint (all MDT and periods; top row: humerus, bottom row: radius and ulna; left to right: anterior, posterior, medial and lateral aspects; black: knife marks, blue: chop marks).

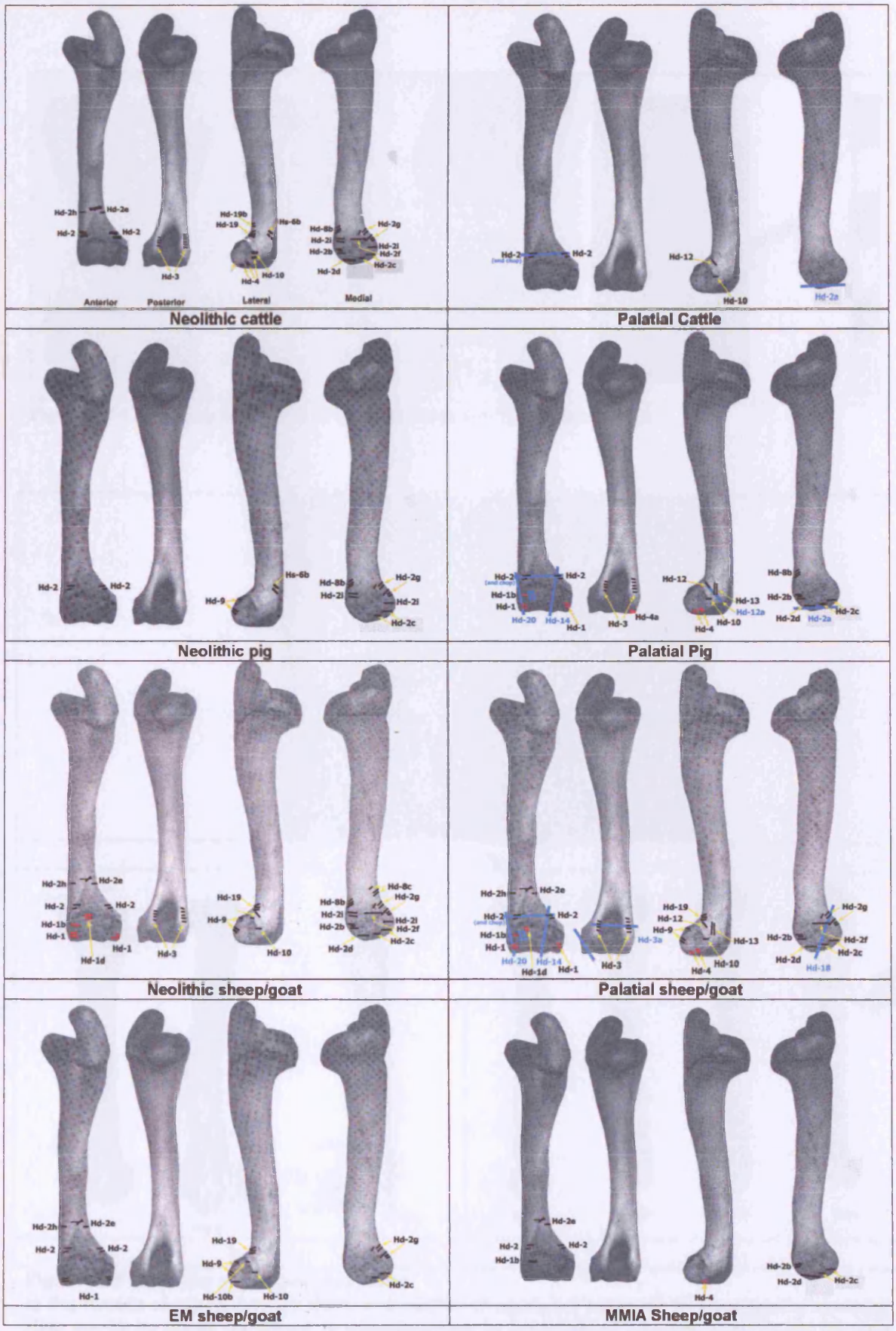


Figure 6:23 Dismembering marks on distal humerus by taxon and sub-phase (black: Group 2 knife marks; blue: Group 2 chop marks; red: Group 1 knife marks)

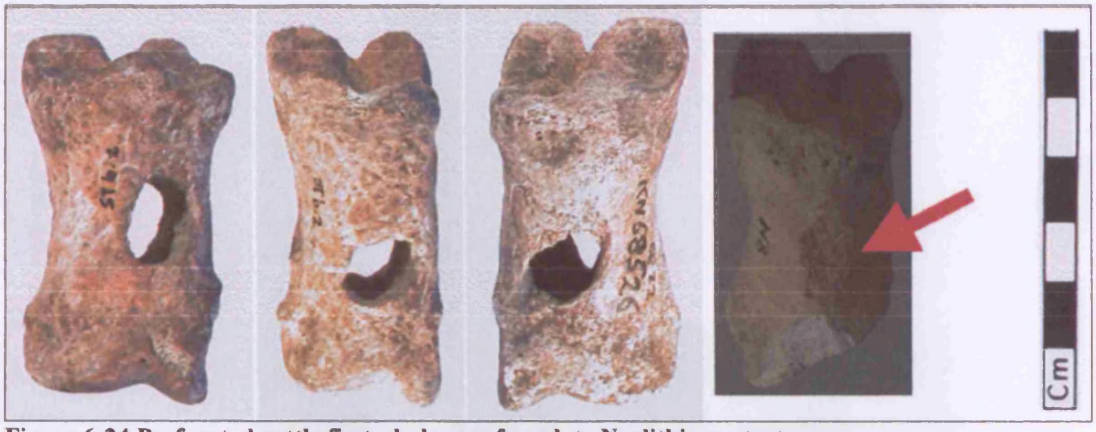


Figure 6:24 Perforated cattle first phalanges from late Neolithic contexts

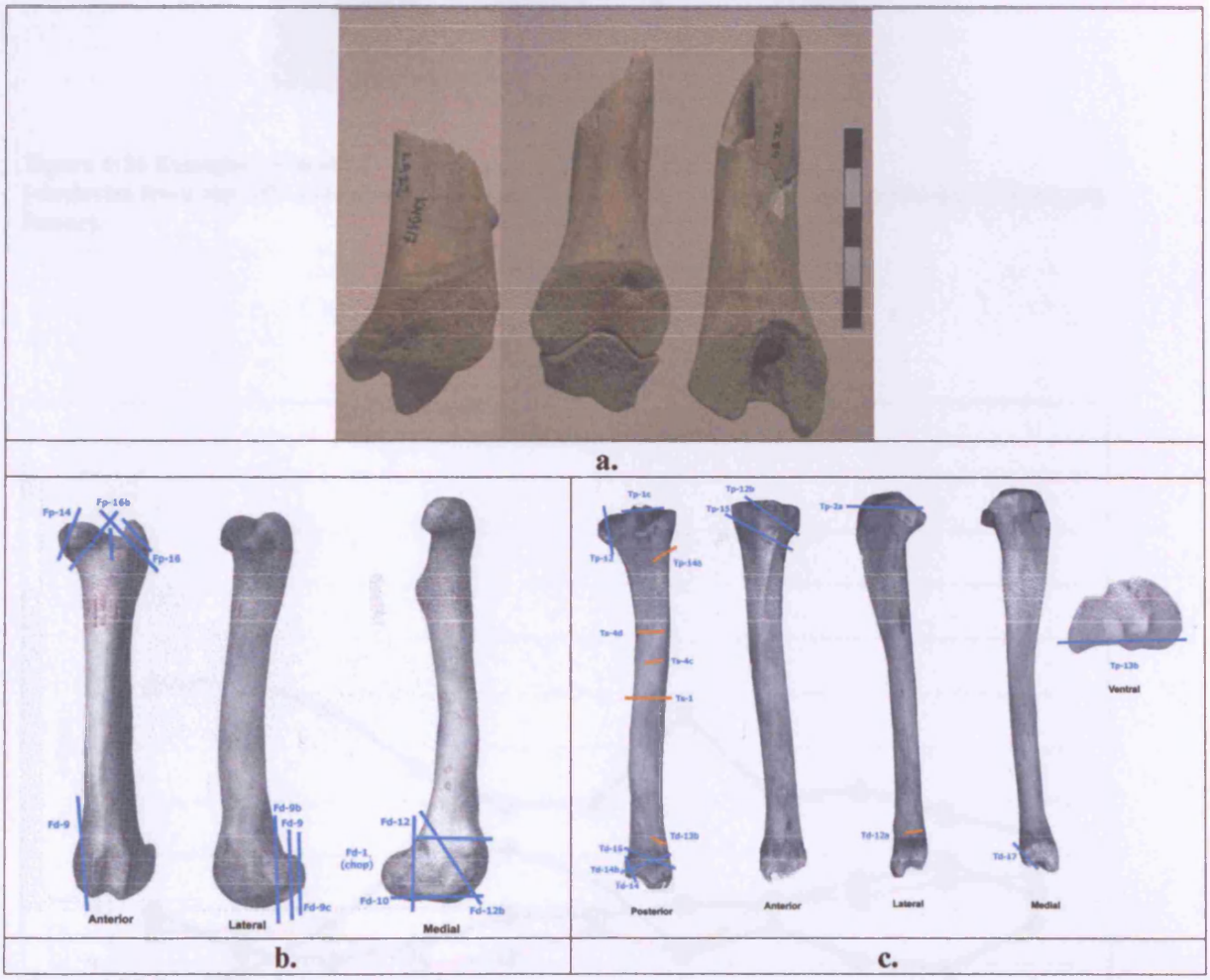


Figure 6:25 Examples of chopped specimens
a) Pig femora chopped through distal articulation (Neopalatial contexts); b) Locations of recorded chop marks on femur attributed to dismembering; c) Locations of recorded chop marks on tibia attributed to dismembering (blue) and marrow extraction (orange).

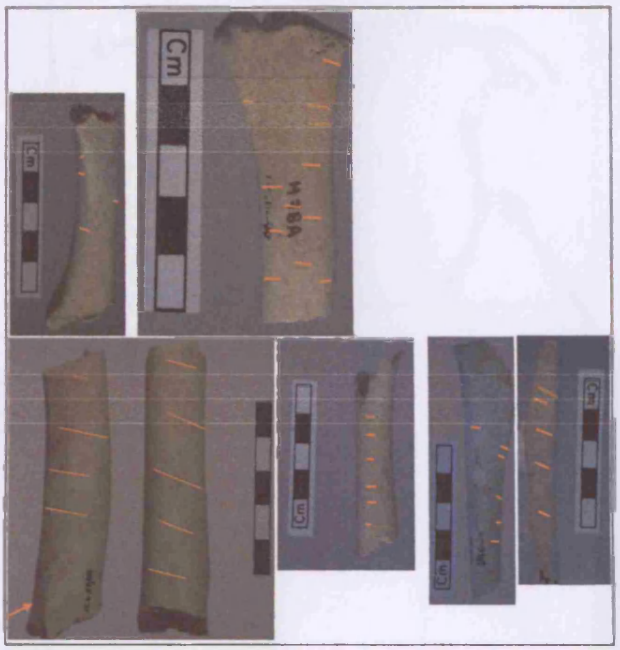


Figure 6:26 Examples of multiple transverse cuts from BA contexts (clockwise from top left: sheep/goat humerus, sheep radius, sheep/goat tibia, sheep/goat femur, pig femur).

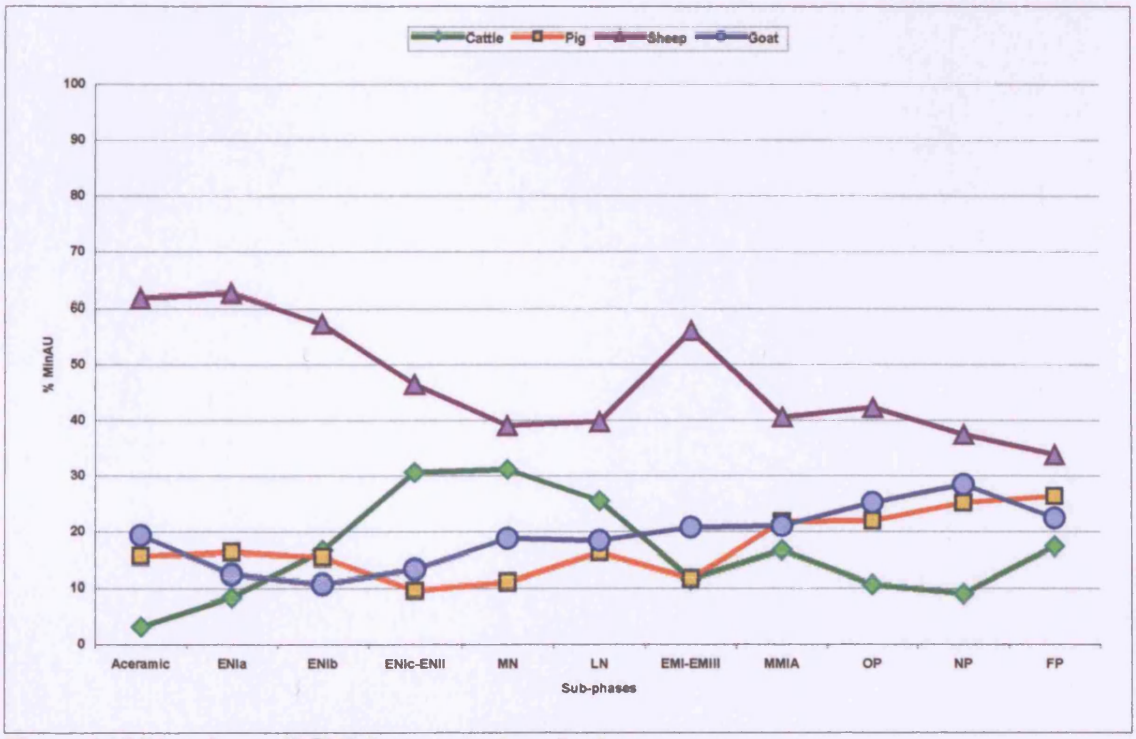


Figure 6:27 Line chart of MDT frequencies by sub-phase

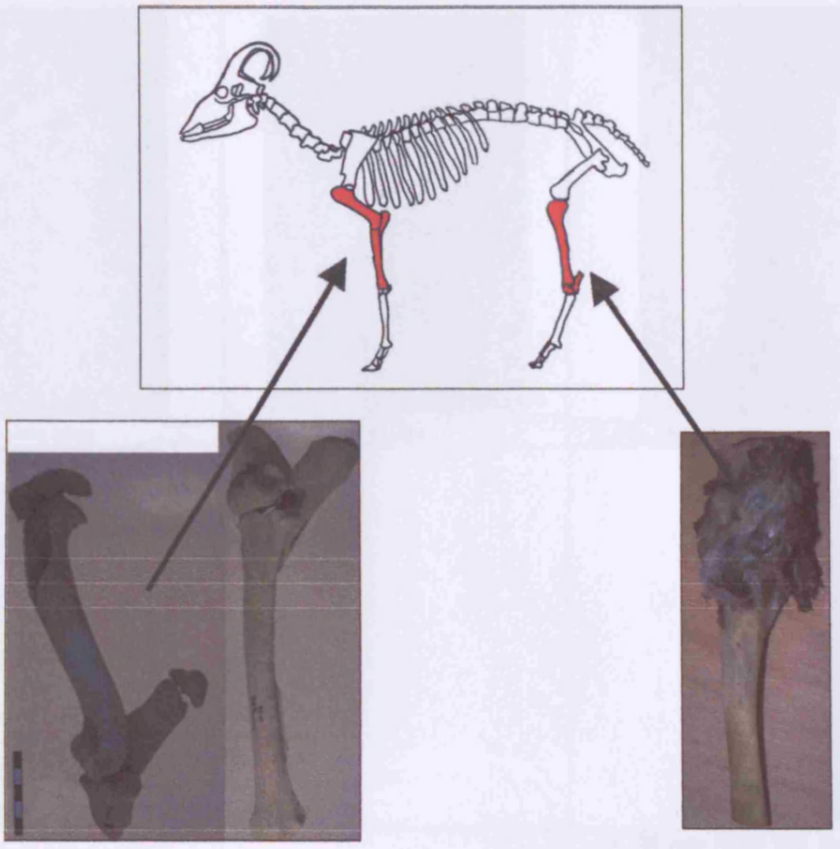


Figure 6:28 Articulating body parts from Pit G
a) location on skeleton of articulating elements identified in Pit G ; b) front leg of goat from Pit G; c) modern example of articulating sheep distal femur and tibia in a stewed joint, showing cartilage left after removal of meat.

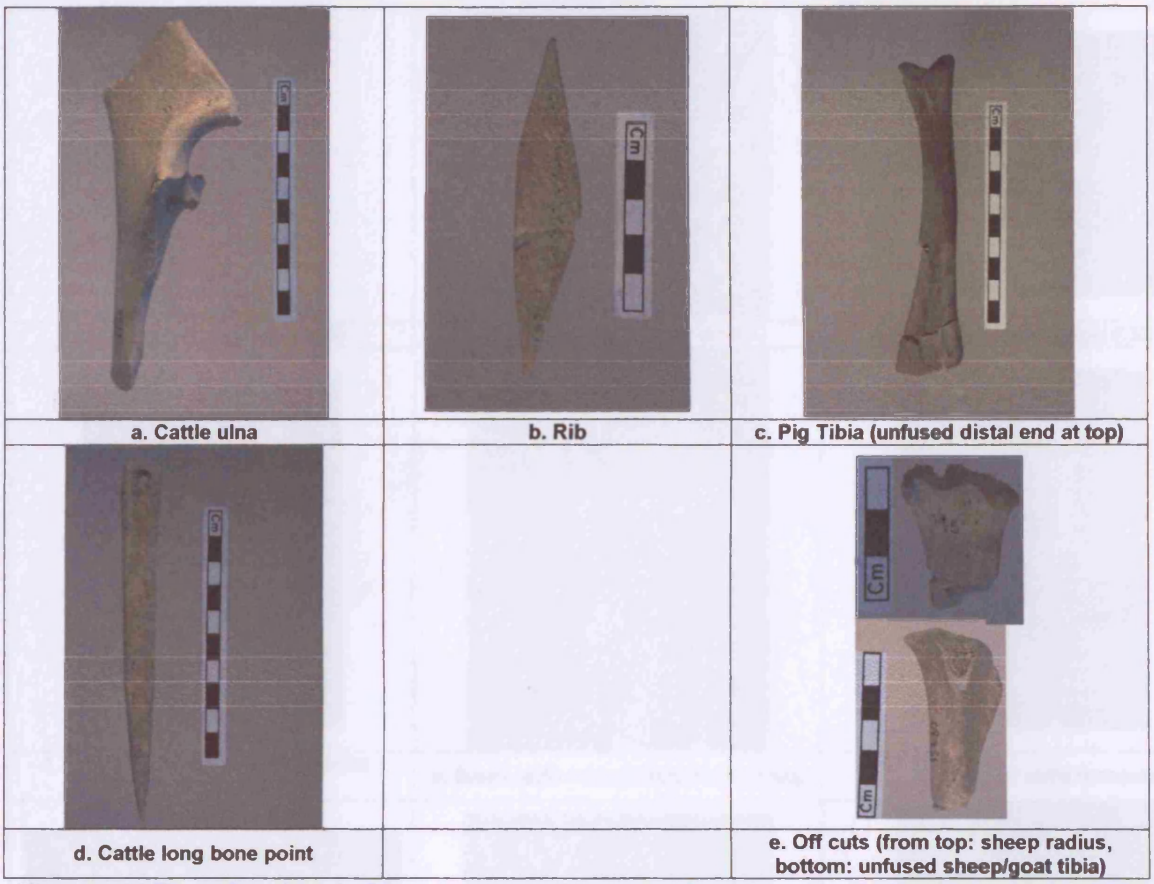


Figure 6:29 Examples of worked bones and possible by-products from Neolithic contexts

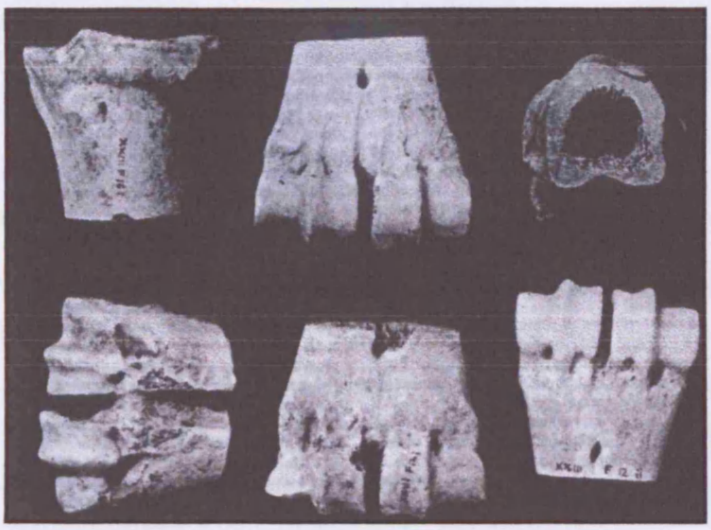


Figure 6:31 Sawn cattle metapodials from Anglo-Saxon Southampton (from McGregor 2001: 47, figure 30).

7 MANAGEMENT

7.1 Introduction

This final analytical chapter explores evidence for management of each of the four major domestic taxa. The assemblage covers a wide chronological span from the earliest introduction of farming to the island, through the purported FN/EM Secondary Products Revolution, to the Palatial period when management for wool and traction is textually documented. The exploration of animal management in such a changing socio-political context is of great interest, since potential changes in animal management may be linked to other phenomena.

The first section discusses the question of the existence of feral animals. The second section is divided into two parts. The first part presents the four types of evidence used (measurements of selected areas of the skeleton, morphological sex data, age profiles, and pathological conditions – all collected as described in Chapter 4) and the ways in which these are interpreted. The second part summarises some basic information from animal behaviour, physiology, and ethnography, which is used in the following sections to interpret the four types of evidence, in combination, for management of cattle, pigs, sheep and goats. In the case of sheep and goats, discussion of management is presented in a single section, fusion data need to be combined for the two species since the speciation of younger individuals and certain body parts is problematic. Data from the various phases of the Neolithic and Bronze Age are tabulated separately, in order to explore diachronic change, following the divisions based on cultural change described in Chapter 3.

7.2 The importance of being feral

As discussed in Chapter 2, the palaeontological record provides irrefutable evidence that *all* animals identified in archaeological contexts at Knossos were either purposely or accidentally introduced by humans, since, due to its geological history and insular character, Crete is well outside their natural geographical distribution. Nevertheless, although it is expected that the majority of the remains belong to animals introduced and managed, and *native* wild animals are absent, the establishment of *feral* populations of any of the MDT is a distinct possibility (cf. Croft 1991: 67 for a similar proposition concerning Neolithic Cyprus). Such populations can be formed by individuals, accidentally or deliberately released into the wild by humans. Indeed, feral goats are still extant on Crete and such populations are present on other Mediterranean islands (e.g., Vigne 1999: 312), while feral boar populations have recently become established

in Britain. Moreover, although claims for the existence of *native* wild animals such as boar, aurochs (e.g., Nobis 1996) and especially lion (Guest-Papamanoli 1996) cannot be taken seriously, it is not impossible that wild individuals of the first two – populations of which appear to have existed on the Greek mainland in prehistory – were captured off-island and released in the wild.

The question of the existence of feral populations is interesting not only from a biogeographical point of view, but also crucial for interpreting the faunal remains for various reasons. First, feral animals revert to a quasi-wild state and in the absence of human control of breeding and (as here) in the absence of non-human predators, body size may increase due to male-male competition, or decrease as a result of overpopulation. Large-scale exploitation of such animals might play havoc with age and sex profiles of deadstock, rendering such evidence meaningless for the exploration of management strategies of the *managed* domesticates (Rowley-Conwy 1995: 116).

Secondly, the presence of such feral populations would give some credence to models suggested for the exploitation of areas considered agriculturally marginal in the FN, and which were supposedly colonised because of the opportunity to supplement a diet based primarily on cultivated crops and domesticated animals by hunting (Watrous 2001). Thirdly, establishing whether or not such populations were available for exploitation provides an insight into the meaning of hunting iconography in Palatial contexts. It may help us to assess whether such scenes acquired a symbolic meaning through actual local practice, or whether they were part of an iconographic repertoire of off-island provenance.

Discrimination between feral, or for that matter truly wild, individuals and taxonomically identical managed animals of the same species is problematic. The method used routinely to-date is assessment of metrical evidence. The problems posed by using such evidence to differentiate between wild and domestic individuals have been discussed by Rowley-Conwy in the context of the purported adoption of animal breeding by western European hunter-gatherer populations. Rowley-Conwy has drawn attention to size differences between wild populations with different geographical distributions (reflecting local availability of food resources and/or founder effect) and the overlap in size of domestic males and wild females, since in wild populations sexual dimorphism especially in size may be very marked.

Additional limitations apply to the use of metrical data for identifying *feral* individuals. First, in the earlier phases of the 'feralisation' process, feral animals should be expected to fall within the same size range as the populations of domesticates from which they derive. Subsequently, absence of human management may lead to behavioural traits like male-male competition,

which favour size increase or, if the founder domestic population was large-bodied (as would be expected for very early Neolithic assemblages), failure to decrease in size in contrast to managed animals. In order for a difference in size to be observable, it is necessary for feral animals to increase in size and/or for domesticates to decrease[1]. Increased or static size of feral animals is not inevitable, especially in an insular geographical context where food resources may be limited, predators absent and suitable habitats fragmented. In such a context individual populations may be small and isolated, the gene pool restricted and male–male competition limited – cf. the observation by Legge and Rowley-Conwy that deer in wooded environments form small groups in which sexual dimorphism is not marked (Legge and Rowley-Conwy 1988). Likewise, decrease in the size of domesticates is not inevitable and depends on the aims and nature of human management. Average body-size of domesticates could increase as a result of the introduction of new breeds and/or the selective breeding of animals of a size suited to novel uses. For example, larger cattle may be selectively bred if there is a demand for specialised traction animals. Such changes may also be reflected in the changing ratios of male/female animals kept to adulthood, deduced from metrics and the morphological criteria discussed below. Finally, climatic change may affect habitats and food availability for both feral and domestic animals, while competition with humans for land may also lead to 'insular' phenomena in wild populations on larger landmasses. For example, von den Driesch observed a decrease in size of red deer through the Neolithic and BA in Thessaly, in central mainland Greece (von den Driesch 1987).

Evidently, metrical data are problematic and probably not reliable in isolation. Some researchers have also explored other indices, such as build and morphology of muscle insertions, which, due to their different lifestyle, may be more pronounced in wild and feral animals (e.g., Wilkens 1996). Indirect support may be provided to metrics by artefactual evidence, for example, hunting/trapping implements. In the case of Knossos, clear artefactual evidence is absent in the Neolithic – there are no stone or other objects which could qualify as arrow or spear points, although it could be argued that the latter were made of perishable materials (e.g., wood). For later periods it is difficult to assign precise uses to implements, since they could have been used equally for hunting or for warfare. Iconography, on the other hand, poses different problems and cannot be used as proof in isolation.

[1] Early populations of domesticates may have been free of selective pressure for larger body-size, or, human control may have intentionally or unintentionally selected for smaller animals. It has been variously argued that body size decreased due to poorer diet and/or preferential retention of smaller-bodied and thus more manageable animals (especially males) and/or for the absence of selective pressure from competition between males, as a consequence of the slaughter of most males before breeding age. As this trend to decreased body-size is widely attested from large wild and earliest domesticates to smaller later domesticates, it is legitimate to infer that any subsequent changes towards a larger size may be linked to new tasks performed by the animals, to the restoration of selective breeding and/or to improved feeding regimes.

The possible existence of feral populations at Knossos is reviewed in the light of available metrical data, below for each of the individual MDT (7.4 cattle; 7.5 pigs; 7.7 sheep; 7.8 goats).

7.3 Methods

7.3.1 Metrical data

Selected measurements are analysed which yielded at least 50 examples per taxon, per type, for all sub-phases combined. This low threshold, essentially not statistically valid, was imposed by the paucity, in many cases, of measurements, resulting from the pre- and post-depositional history of the assemblage. In the case of cattle, the rarity of the species and intensive fragmentation for within-bone nutrient extraction are the main causes for this paucity. Rarity is also a problem for pigs and goats, which have suffered additional breakage from storage and transportation, as have sheep bones. All selected measurements are presented mainly in histograms plotting grouped frequency distribution. Fusion state (fused, unfused, fusing and indeterminate) of each specimen is shown using different colours.

Measurements are drawn upon to investigate first the likelihood of existence of *distinct populations* (i.e. domestic and feral[2]), secondly *changes in body-size* of domesticates through time and finally to provide additional information on the *sexual composition* of domestic deadstock.

The evidence is interpreted as follows:

1. The existence of *distinct populations* is assessed on the basis of the range of values for individual measurements, with broad or increasing ranges tentatively suggesting the presence of feral animals. Subsequently, the highest measurements are compared to ones identified as wild[3], and of similar date from other mainland and island sites (Table 7:1); 'outsize' specimens might again be taken as evidence in favour of the presence of feral animals. In the case of pigs, this stage of analysis may be rendered less subjective by comparing the coefficient of variation (CV) of Knossos metrical data with that reported from a modern Turkish population (Rowley-Conwy 1995; Payne and Bull 1988).

[2] The term feral rather than wild is chosen here in view of the conclusions drawn in Chapter 2.
[3] Although there are no systematic studies of the rate of naturally occurring size reduction leading to the creation of pygmy forms on islands ('nanism'), it is unlikely that such changes occur within a few centuries, or even millennia, especially since the island with the introduction of carnivores loses one of its typical insular characteristics, the absence of predators. Therefore, an argument for pygmy 'island' forms developing from mainland wild progenitors is not plausible (*contra* Winder 1986).

2. Taking (1) into consideration, *changes in average body-size* are inferred by comparing the ranges of values between sub-phases for each measurement.
3. Again taking (1) into consideration, normal (symmetrical) distributions of measurements of mature elements suggest culling of roughly equal numbers of male and female individuals which had reached skeletal maturity. These metrical patterns are then assessed in light of morphological sex data (see below). Conversely, assymetrical distributions skewed to the left or right suggest a preponderance of females or males, respectively. Again, interpretation is aided by studies of modern populations of pigs (Payne and Bull 1988), cattle (Higham 1969) and, less systematically, sheep/goats, (Boessneck *et al.* 1964), which have identified body parts exhibiting high levels of sexual dimorphism or age-related variation in size.

7.3.2 Morphological sex data

In addition to metrical data (above), sex ratios are inferred from the morphology of male and female pelves for cattle, sheep and goats and of mandibular canines and sockets thereof for pigs. Increased numbers of adult males may reflect intensified use of certain secondary products: traction in the case of cattle, and wool and hair in the case of sheep and goats. Alternatively, males of all or some species may have been kept to an older than optimal age for slaughter (optimal in terms of management for primary carcass products), for cultural reasons, such as the symbolism in consuming such large and 'expensively' reared animals. Thus interest here focuses on sex ratios among *adult* animals.

The sex ratios inferred from fused pelves and erupted canines theoretically provide an indication of the relative proportions of males and females surviving beyond the ages of acetabular fusion (6-10 mths. in sheep and goats, 7-10 mths. in cattle) and canine eruption (8-12 mths. in pigs), respectively. On the assumption that males and females of each species were born in similar numbers, these ratios may also reveal any selective mortality of either sex at a younger age. In practice, pelves of mature animals are more sexually diagnostic, and so more easily attributed to male or female (e.g., Boessneck 1969), than those of younger animals and so the sex ratios for sheep, goats and cattle probably relate largely to adult animals – the parameter of prime interest in the investigation of animal management. Likewise, the large canines of adult pigs are more likely to be retrieved than their smaller, younger counterparts. For similar reasons, sex ratios of pigs are biased towards males because large male canines are more easily retrieved, and large male canine sockets more easily recognised, than the smaller canines and canine sockets of females. All things being equal, pelves of adult male cattle, sheep and goats are more robust than those of adult females and so are less likely to break at the acetabulum into fragments small

enough to be overlooked in excavation. Overall, therefore, morphological sex ratios are likely to exaggerate adult survivorship of males in all four MDT, and especially so in pigs.

7.3.3 Age data

Age data are analysed in the following ways. First, the more problematic fusion data are compared with dental data, in order to identify potential discrepancies not explainable by post-depositional processes (e.g., scavenger attrition) and, more specifically, as a check on the possibility that dental data are biased by differential discard of mandibles of different ages. In interpreting the results of this comparison, it must be born in mind that the absolute ages conventionally assigned to developmental stages, especially epiphyseal fusion and dental wear, may be quite inaccurate. Thus, only major discrepancies between dental and post-cranial evidence will be treated as significant.

Secondly, dental *only* data are used to create age profiles and provide insights into the aims of management. They are preferred for this task as they offer a more precise and continuous record of age at death. Thirdly, the frequency of elements belonging to clearly neonatal/foetal individuals is discussed, as their presence implies rearing in the immediate vicinity (i.e. within the settlement itself), although further interpretation of the cause of death – that is whether the particular individuals were victims of culling or disease – is not easy (Halstead 1998: 4); incontestable evidence in the form of butchery marks on neonatal specimens is absent from the present assemblage. Finally, the fine-grained information on age-at-death provided by tooth eruption and wear of the younger animals offers an insight into seasonality of occupation at the settlement (cf. Halstead *in press* a).

7.3.4 Pathologies

Pathologies are not a very systematically explored area of faunal studies and interpretation of aetiology can be problematic due to equifinality. Some useful studies, of modern osteological collections, however, have concentrated on the manifestation of traumatic injuries on elements of the lower legs and feet (metapodials and phalanges) of cattle with known work history (e.g., Bartosiewicz *et al.* 1997; de Cupere *et al.* 2000), thus providing somewhat safer grounds for relating archaeologically attested pathological conditions to plausible causes. These conditions (emargination, eburnation, condyle extension and osteophytic growth) were observed in the Knossos assemblage and recorded. Although other conditions were also recorded, these are the most frequent and potentially most interesting from the point of view of providing insights into patterns of animal management.

7.3.5 Models for interpretation: animal behaviour, physiology and ethnography

All of the above evidence is interpreted in combination, making heuristic use of modern studies of animal behaviour and physiology and of ethnographic studies of traditional animal management (e.g., Garrard 1984; Halstead 1998; Koster 1977; Noddle 1990; Payne 1973; Redding 1984; Dahl and Hjort 1976). The use of the above in interpreting archaeological data entails uniformitarian assumptions (i.e. that behaviour and physiology of the relevant species in the past were essentially the same as those of their modern descendents) (Noddle 1990) and may also involve optimising assumptions about human decision making (Halstead 1998) and so must be undertaken with caution.

7.3.5.1 *Animal behaviour and physiology*

Of relevance to interpreting faunal data are details concerning physiological characteristics of MDT. Female *sheep* and *goats* under pre-modern conditions of management start bearing young at around two years of age, and continue to do so until 7-10 years old. They normally produce one lamb or kid, but occasionally two (goats more often than sheep), goats after a gestation period of five months and sheep of five and a half months (Koster 1977; Payne 1973; Redding 1984). On Crete in the recent past, unimproved breeds gave birth between December and January (Halstead: 2003 Knossos field notes). The productive age for castrated male sheep is between 2-3 years and 5-6 years, when it is reported that they produce the best quality wool/hair, which then declines (Killen 1964). Female *pigs* breed between two and 6-8 years of age, produce litters of six or more piglets after a gestation period of three months and three weeks, making it thus possible to produce up to two and a half litters per year, provided adequate nutrition is available – which would not necessarily have been the case in prehistory. Finally, breeding age for cattle is between 3-4 and 10-12 years old, during which single births after a gestation period of nine months are most common (Halstead *field notes*; Dahl and Hjort 1976).

7.3.5.2 *Ethnographic models of management*

The study of traditional contemporary and historical animal breeding has helped researchers understand how the breeding of managed domesticates can be manipulated in pre-modern conditions to generate primary and secondary products and how this is reflected in the age and sex composition of groups of animals. More specifically, based on ethnographic observation of flocks of goats in Turkey, Payne (1973) has presented simplified models of management for meat, milk and wool/hair production which are also largely relevant to sheep and cattle (Legge 1981; Rowley-Conwy 2000). According to these models, an emphasis on the production of *milk* requires the slaughter of surplus infants (i.e. males and any females not required for

reproduction) at ca. 1 month, and weaning of young females destined for reproduction at ca. 2 months after birth, after which all milk can be collected for human consumption (usually converted into cheese/yoghurt). Management aimed at maximum yield of meat requires the slaughter of surplus animals (again mostly males) as juveniles or sub-adults (say between 6 months and 2-3 years of age). In both the meat and milk models, the adult segment of the population consists overwhelmingly of mature females. A strategy targetting maximum *wool/hair/traction* output would be characterised by increased numbers of adult males, most probably castrates, which are more productive in terms of such secondary products, and therefore more even representation of the two sexes in the adult segment of the population. A *combined milk/meat* strategy would be characterised by slaughter of animals between three to twelve months old, which would allow both extraction of milk for human consumption and reasonable meat yields. Male cattle need to reach their third or fourth year, before being effective as draught animals although training may begin at an earlier age (Halstead *field notes*).

As Payne pointed out (Payne 1973), these are models of specialised management largely developed within market economies catering for urban populations, and as such have essentially heuristic value for archaeological applications. Consequently, they should be used to interpret archaeological faunal assemblages with the express understanding that they represent indications of the *potential* for intensive specialised production rather than simple records of which products were *actually* exploited.

7.4 Cattle

7.4.1 Distinct populations and body-size changes?

Insofar as the status of cattle is concerned, metrical data are contradictory, not least because of their rarity. Measurements fall largely within reported ranges for domesticates from other contemporary sites on the Greek mainland, but a few cases overlap with ones identified as wild (i.e. aurochs). In the first category are almost all astragalus GLl, radius Bp, tibia Bd, scapula GLp and BG measurements. There are three exceptions: a single radius Bp measurement from an ENIc-ENII context falls outside the range for domesticates from the Neolithic sites used here as comparanda; a tibia Bd measurement from a Palatial context falls within the range of measurements for specimens identified as aurochs at EBA-MBA Pefkakia (Table 7:1); and one scapula BG from an LN context is larger than an aurochs identified from EB-LB Lerna, although several examples could be categorised as 'wild' if compared to the aurochs range from LN Makriyialos I. In the second category, measurements outside the 'domestic' range are observed more frequently for humerus Bd, throughout the Neolithic and in the Palatial period, and for metacarpal and metatarsal Bd, throughout the Neolithic.

Table 7:1 Selected comparative measurement ranges for cattle
(mm.; black: cattle; grey: aurochs; * approximate values; see end of table for references).

		GLp	LG	BG	Bp	Bd	GLl	GLm
				MN				
Asagi Pinar II-IV	Astragalus						57.0-74.0*	
Sitagroi III	Astragalus						59.0-78.0*	
				LN				
Makriyialos	Scapula	61.0-85.0		36.0-65.0				
	Radius				72.0-95.0			
	Metacarpal					42.0-68.0		
	Tibia					57.0-72.0		
	Astragalus					38.0-48.0	59.0-74.0	54.0-68.0
	Metatarsal					50.0-64.0		
Phaistos	Scapula	61.0	54.7-59.8	42.8-51.9				
	Metacarpal					65.0		
	Tibia					55.1-58.5		
	Astragalus					37.0	61.3	56.0
	Metatarsal					50.8-53.7		
Dhimini	Humerus					64.0-79.5		
	Radius				77.5-79.5			
	Metacarpal					55.0-68.0		
	Tibia					54.5-69.0		
	Astragalus						60.0-67.5	
	Metatarsal					51.5-52.5		
Aghia Sophia	Scapula							
	Humerus					75.0		
	Radius				80.5			
	Metacarpal					56.0-58.5		
	Tibia					55.5-60.5		
	Astragalus						64.0-71.0	
				FN-MB				
Pefkakia	Scapula		58.0	46.0-59.0				
	Radius				69.0-88.0			
	Metacarpal					51.5-69.0		
	Tibia					52.0-67.0		
	Astragalus					35.5-47.0	56.0-61.0	52.2-64.5
	Metatarsal					47.0-63.0		
				EBA-LBA				
Tiryns	Metacarpal					40.0-72.0		
	Astragalus					32.0-50.0	48.0-75.0	
	Metatarsal					40.0-60.0		
Lerna	Metacarpal					56.0-67.0		
	Astragalus							
	Metatarsal					41.0-49.0		

References				
	Asagi Pinar	Benecke 1998	Dhimini	Halstead 1992a
	Sitagroi	Bökönyi 1986	Aghia Sophia	von den Driesch & Enderle 1976
	Makriyialos	Halstead *in prep.*	Pefkakia	Jordan 1975
	Phaistos	Wilkens 1996: 254-61, appendix 20.1)	Tiryns	von den Driesch and Boessneck 1990
	Lerna	Gejvall 1969		

Table 7:2 LA measurements for sexable cattle pelves

Phase	LA (mm)	Sex
MN	58.1	♀
MN	60.0	♀
ENIc-ENII	62.0	♀
LN	64.4	?♀
ENIb	65.0	♀
MN	65.4	♀
LN	66.7	♂
MN	71.1	♂
MN	72.3	♂
ENIc-ENII	77.5	♂

Clearly, not all metrical data tell the same story. There is evidence for the existence of a few very large individuals, which could belong to hunted feral populations or might alternatively result from husbandry under favourable nutritional conditions, or even from selective breeding for large size. Some light is shed on these alternative interpretations by non-metrical evidence. First, it should be noted that the large Knossos specimens do *not* exhibit the pronounced muscle attachments or thick diaphyseal bone walls common on skeletal elements of wild individuals. Thus, there is no indication that the larger individuals had enjoyed a radically different lifestyle from their smaller counterparts. Secondly, metrical data for the few sexable pelves show that the smallest females were identified only among the smaller specimens (Table 7:2); while the presence of large females would have favoured the existence of a separate (larger) feral population, their absence is consistent with a single population in which size variation is substantially a product of sexual dimorphism. This conclusion is supported by the comparison with a true wild assemblage from the Bulgarian site of Goljamo Delçevo III, where wild cattle astragalus GLl are well outside the range of their Knossian counterparts.

The most parsimonious hypothesis, therefore, is that the Knossos cattle represent a single domestic population. Indeed, cattle are less likely than other taxa to have been able to establish viable feral populations because of feeding requirements (the island is not very well suited for providing adequate food for animals of their body size and feeding habits) and slow breeding (single offspring and long gestation periods), while isolated parts of the island away from intensive human settlement during most of prehistory, like the mountainous areas and upland plateaux (e.g., Katharo, Lasithi), would arguably have been unsuitable for the establishment of such populations, because of winter snow cover.

When measurements are available for all sub-phases (radius Bp, humerus and tibia Bd and astragalus GLl – Figure 7:1 and Figure 7:2) they hint at *reduction* of the average body size between the earlier Neolithic (Aceramic-ENIa) and the Prepalatial period, followed by an increase in the Palatial period (the latter suggestion is tentative since measurements from this

period are very rare). The timing of size decrease is unclear, due to the scarcity of cattle measurements from Aceramic, ENIa and ENIb contexts.

In conclusion, analysis of measurements suggests that it is legitimate to use all sex and age data to explore management strategies, because a single population of cattle is represented at Knossos. Size decrease will be assessed below in the light of these data, as it may be related to changes in management practices.

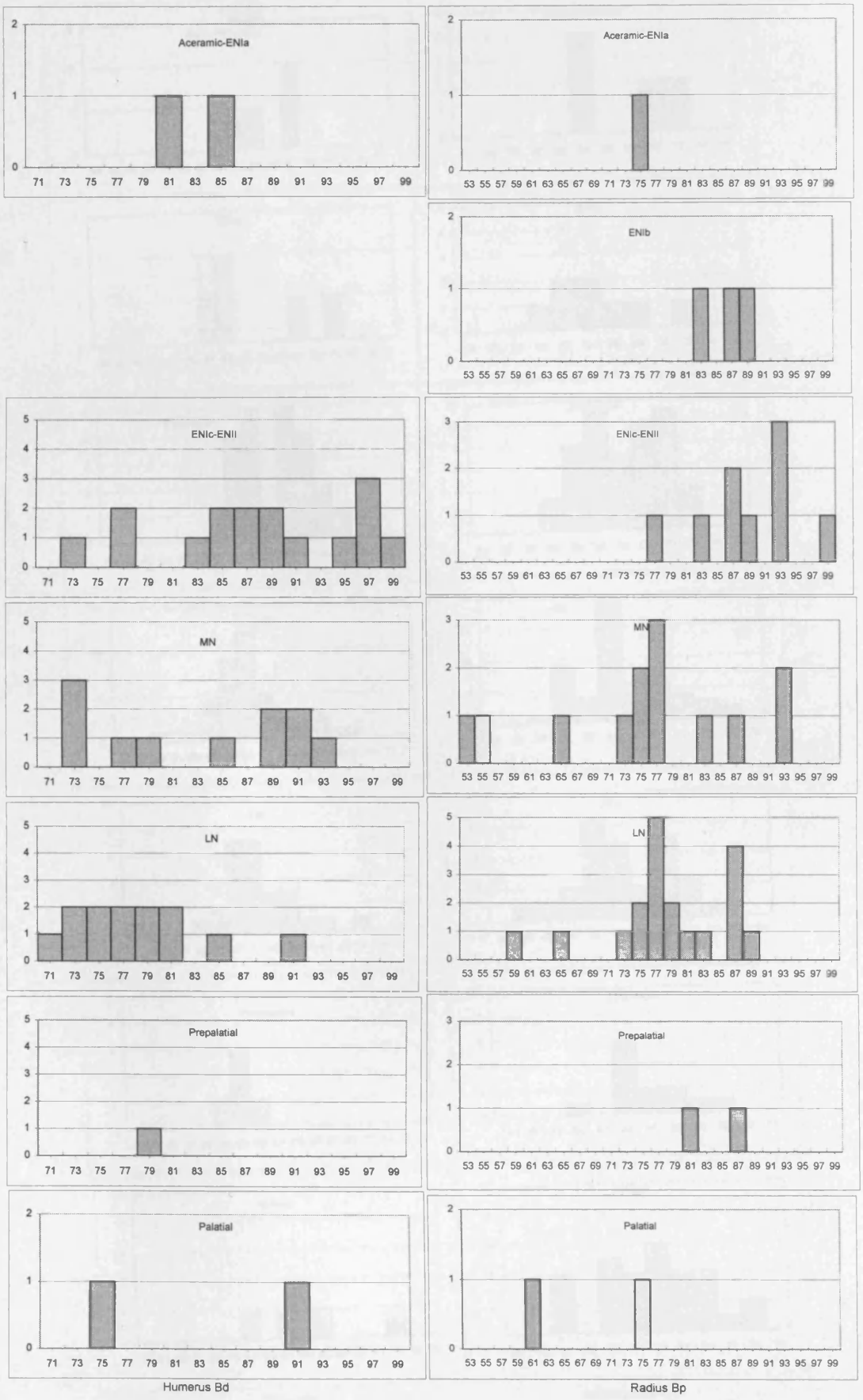


Figure 7:1 Grouped Frequency Distribution histograms for cattle humerus (Bd) and radius (Bp) (white: unfused; grey: fused; dark grey: fusing)

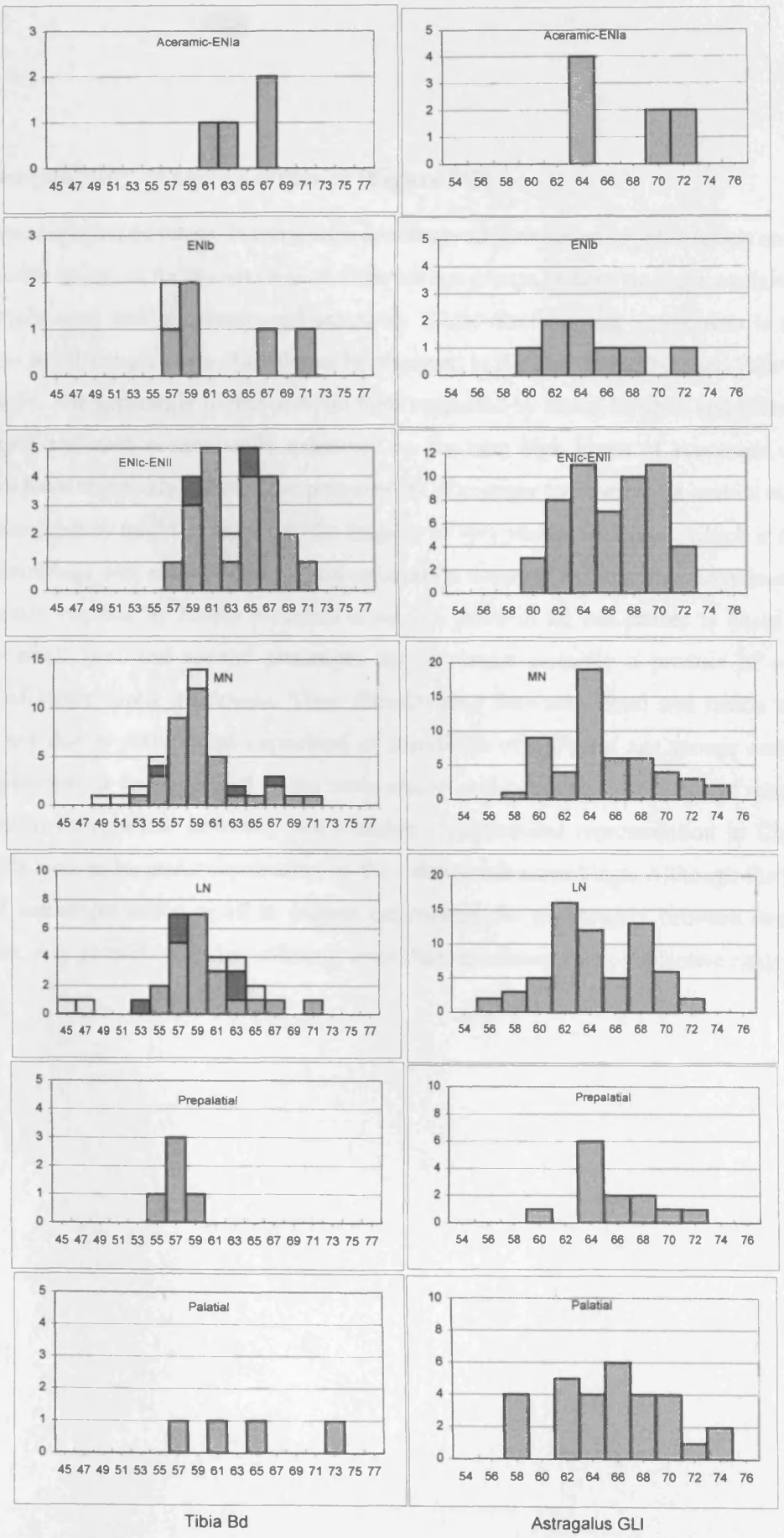


Figure 7:2 Grouped Frequency Distribution histograms for cattle tibia (Bd) and astragalus (GLl) (white: unfused; grey: fused; dark grey: fusing)

7.4.2 Compatibility of ageing evidence (Figure 7:3)

In most assemblages, no major discrepancies are observed between epiphyseal fusion and dental wear/eruption evidence for the survival of different age groups, other than those explainable by small sample sizes and/or depositional processes. Slight discrepancies attributable in the first instance to small sample sizes of teeth can be observed in the Aceramic-ENIa and Palatial sub-assemblages. The apparently higher survival rates suggested by fusion in ENIb and ENIc-II sub-assemblages are most economically explained by the very high levels of scavenger attrition which will have negatively affected the preservation of younger (unfused) post-cranial elements. The LN discrepancy might be related to the fragility of very young mandibles, which in this part of the assemblage was exacerbated by post-excavation damage. Finally, the anomalously high survival rates implied by fusion evidence at ca. 1.5 years in all sub-phases is based on the relatively small first and second phalanges and is almost certainly a product of selective recovery of larger fused specimens. Thus, discrepancies between dental and fusion data are arguably not due to differential deposition of mandibles of different age groups and so the following analysis is largely based on the more precise and informative evidence of mandibular teeth. It must be recalled, however, that analysis of anatomical representation in Chapter 6 found cattle teeth to be *under*-represented in the Palatial sub-assemblage. Although the Palatial sample of mandibles is too small to expose any meaningful discrepancy between dental and fusion data, it is possible that the 'missing' mandibles are drawn from a selective range of age groups.

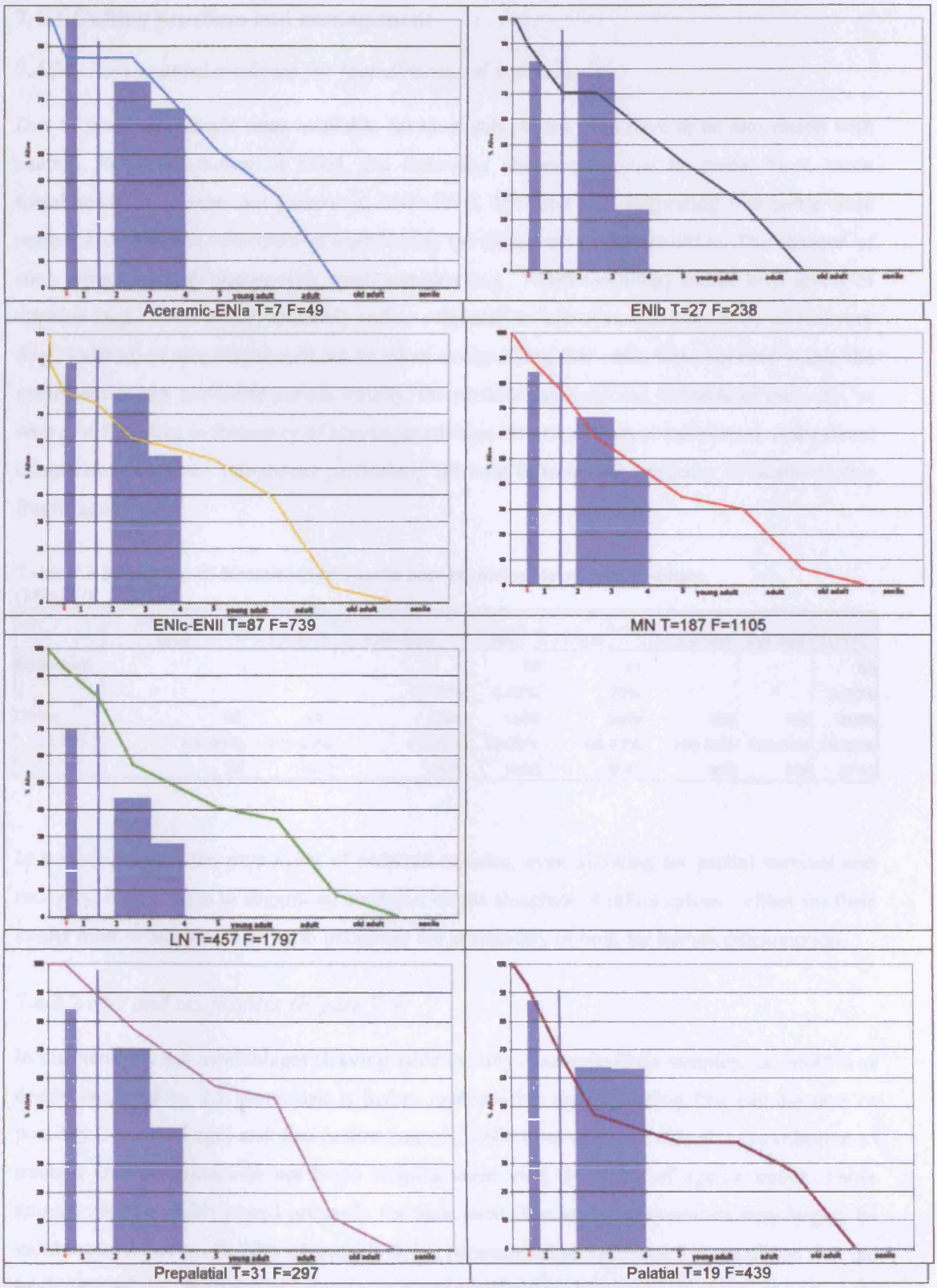


Figure 7:3 Charts comparing cattle age data for individual sub-phases (fusion: bars; mandibular tooth ageing: cumulative curves; MinAU; T=combined MinAU counts for loose teeth and mandibles; F=combined MinAU counts for all post-cranial material providing fusion information).

7.4.3 Culling practices and management

7.4.3.1 *Post-cranial evidence for foetal/neonatal individuals*

Due to the small sample sizes available for most sub-phases, data have to be interpreted with caution. With this caveat in mind, the following observations can be made. First, cattle foetal/newborn remains are present in ENIc-ENII, MN and LN, suggesting that cattle were reared in or near the settlement at least during the latter part of the Neolithic. The absence of such remains in sub-phases with small samples (e.g., Aceramic-ENIa) and/or high levels of attrition (e.g., ENIb and Prepalatial) and/or subjected to non-systematic methods of recovery (e.g., Palatial) (Table 7:3) should not be taken as signifying that cattle were not bred within the settlement in any particular period. Finally, the variable intensity and methods of recovery, as well as differences in frequency of scavenger attrition between different sub-phases, make direct comparisons between sub-phases particularly difficult in terms of frequency of deaths in this fragile age group.

Table 7:3 Frequency of foetal/neonatal cattle post-cranial material by sub-phase (MinAU).

	Aceramic-ENIa	ENIb	ENIc-ENII	MN	LN	Prepalatial	Palatial	TOTAL
New-Born	-	-	1	16	41	-	-	58
	-	-	0.10%	0.80%	1.20%	-	-	0.70%
Older	96	437	1324	1969	3499	605	756	8686
	100.00%	100.00%	99.90%	99.20%	98.80%	100.00%	100.00%	99.30%
	96	437	1325	1985	3540	605	756	8744

In no sub-phase is the proportion of neonatal remains, even allowing for partial survival and recovery, high enough to suggest an emphasis on the slaughter of infant calves – either for their tender meat or skins or in order to maximize the availability of milk for human consumption.

7.4.3.2 *Age and sex profiles (Figure 7:4)*

In the Neolithic sub-assemblages (leaving aside the tiny Aceramic-ENIa sample), ca. 30-45% of deaths occurred by 2.5 years, that is before reproductive age (assuming first calving at 3 or possibly 2 years of age) and also before animals could have made an effective contribution to traction (recent farmers do not begin training oxen until 2-3 years of age or more). These animals were arguably reared primarily for their meat. The same interpretation may largely be valid for a further ca. 10-30% of animals dying between 2.5 and perhaps 5 years of age (i.e. the beginning of the 'young adult' stage), as these would have been able to make, at best, only modest contributions to reproduction or traction requirements. The remaining 30-50% of animals that died during adulthood could potentially have been breeding stock and/or work animals, although iconographic evidence warns that large adult cattle may have also been

valued as symbolic resources. Thus, the Neolithic sub-assemblages exhibit a gradual pattern of post-infancy mortality, suggestive of management for a range of products. Differences between sub-phases (e.g., the absence of old adults in ENIb) are perhaps attributable in large measure to small sample size.

The two Bronze Age sub-assemblages are rather small, but distinctive enough to deserve comment. The Prepalatial sub-assemblage has the highest proportion of adult deaths (ca. 40%; ca. 60% for young adults, adults and old adults combined), raising the possibility of increased emphasis on management for secondary products (milk and/or traction). The Palatial sub-assemblage has the highest proportion of young (<2.5 years) and old adult deaths, perhaps indicating consumption of a combination of 'gourmet' young meat and elderly animals culled from secondary products management, but the under-representation of mandibles in this sub-assemblage (above 6.2) demands caution in inferring husbandry strategies from debris of consumption activity.

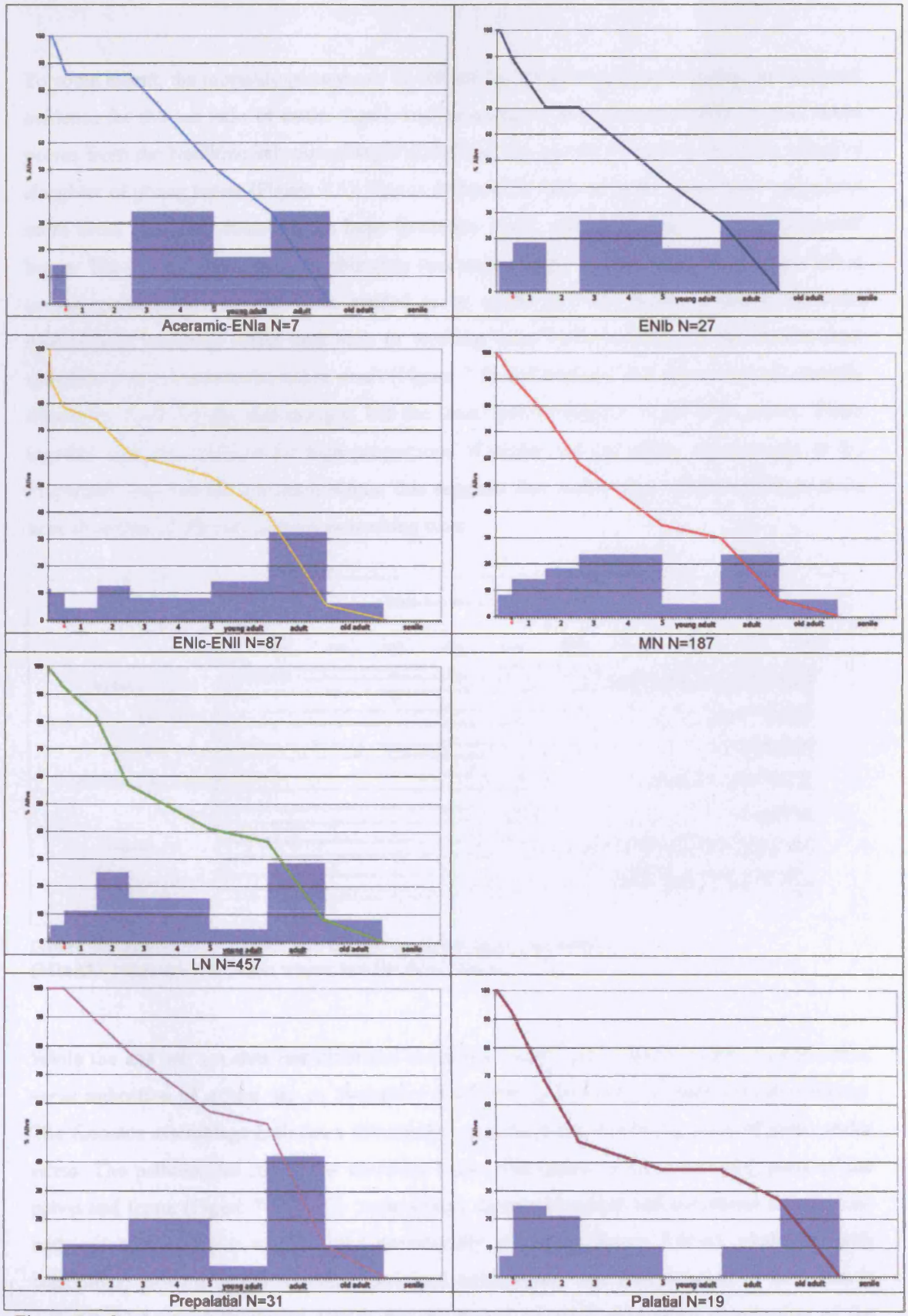


Figure 7:4 Cattle: Survivorship curves and histograms showing percentage of deaths for each age stage
(N=combined MinAU counts for loose teeth and mandibles).

To some extent, the mortality picture can be refined by considering morphological and metrical evidence for the sex ratio of cattle. Again leaving aside the tiny Aceramic-ENIa sample, sexed pelves from the Neolithic sub-assemblages include as few as 15-25% males, implying selective slaughter of young males (Figure 7:5). This is compatible with the metrical evidence suggesting more small (probably female) than large (probably male) specimens among fused postcranial bones. The age and sex data in combination thus suggest that, during the Neolithic, cattle killed young, presumably for their meat, tended to be males and that adults tended to be cows (presumably breeding) rather than bulls or working oxen. Unfortunately, for the Bronze Age, samples of sexed pelves are rather small (Figure 7:5) and metrical data for the highly sexually dimorphic front leg are also meagre, but the sexed pelves suggest ca. 35-40% males. Taken together with the evidence for high proportions of adults and old adults, respectively, in the Prepalatial and Palatial sub-assemblages, this suggests that males were now more likely to be kept alive into adulthood, perhaps as working oxen.

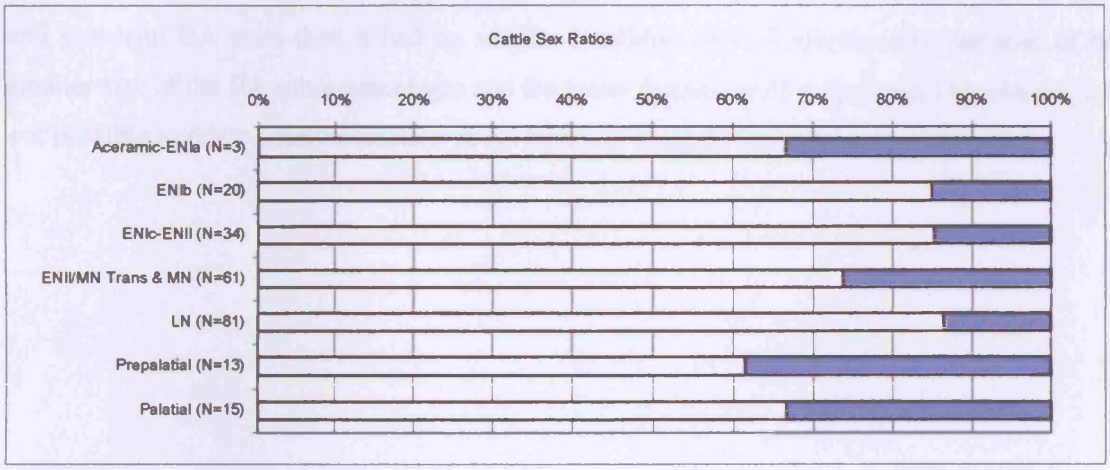


Figure 7:5 Frequencies of male and female cattle pelves by sub-phase (MinAU; N=number of cases; white: female; blue: male).

While the age and sex data just discussed essentially shed light on the *potential* uses of cattle, some indication of *actual* use or husbandry conditions is provided by pathological evidence. The Knossos assemblage includes a fair number of cattle bones exhibiting signs of joints under stress. The pathological conditions observed were: eburnation on the articulating parts of the pelvis and femur (Figure 7:6a and b respectively); distal metacarpal and metatarsal articulations with extended articular surfaces and occasionally grooving (Figure 7:6c-e); phalanges with osteophytic growths and emarginated proximal articulations. The interpretation of such data is difficult (Baker and Brothwell 1980), but the highly selective anatomical distribution of the Knossos examples (Table 7:4) suggests that they result from work-related stress rather than

from congenital or age-related conditions. This is especially true for conditions observed on the distal metapodials and phalanges, as shown in studies of modern oxen with known working life histories (e.g., Bartosiewicz *et al.* 1997).

In this light the chronological distribution of these pathological specimens is intriguing: they are strikingly more frequent in the Neolithic (with due allowance again for the small size of the earliest Neolithic sub-assemblages) than in the Bronze Age. The implication – that the use of cattle for work was more frequent and/or more intensive in the Neolithic than in the BA – may seem to contradict the tentative inference of improved male survivorship in the BA. In fact, more detailed analysis of the pathological evidence for the (sexable) pelves shows that stress-related traces are frequent in females (Table 7:5). Thus it seems that adult cows (females) were being used in the Neolithic (possibly from ENI onwards) for traction as well as breeding. Conversely, the lower frequency of pathological evidence for traction stress in the BA might be interpreted in two rather different ways: first, as evidence that increased numbers of adult males were kept for purposes other than traction (e.g., as large and prestigious animals for slaughter); or, secondly, as evidence that traction placed significantly less stress on the skeletons of large and powerful BA oxen than it had on smaller Neolithic cows. Unfortunately, because of the smaller size of the BA sub-assemblages and the lower frequency of pathological specimens, it is not possible to relate possible traction stress to sex of animal (Table 7:5).

Table 7:4 Frequency of probable traction related pathologies in cattle (MinAU; skeletal elements of cattle by anatomical unit and sub-phase; excluding shaft fragments, unfused epiphyses, foetal/newborn and other immature specimens).

% Pathological specimens per part of skeleton									
	PE	Fp	MCp	MCd	MTp	MTd	PH1	PH2	PH3
Aceramic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%
ENIa	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40.0%	0.0%
ENIb	9.5%	0.0%	0.0%	36.4%	0.0%	62.5%	15.7%	12.2%	26.7%
ENIc-ENII	2.2%	15.4%	6.3%	25.9%	2.1%	11.1%	11.6%	8.2%	8.1%
ENII/MN Trans & MN	7.3%	54.2%	1.3%	20.8%	0.0%	8.3%	18.0%	3.1%	3.3%
LN	7.0%	10.8%	5.1%	24.4%	1.0%	17.9%	6.7%	3.2%	4.1%
Prepalatial	0.0%	11.1%	0.0%	6.3%	0.0%	0.0%	3.3%	2.4%	0.0%
Old/Neo-Palatial	9.1%	0.0%	0.0%	6.7%	0.0%	0.0%	6.7%	1.6%	0.0%
Final Palatial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%

MinAU of pathological specimens										
	PE	Fp	MCp	MCd	MTp	MTd	MPd	PH1	PH2	PH3
Aceramic									1	
ENIa	1								2	
ENIb	2			4		5		8	6	8
ENIc-ENII	1	2	4	14	1	5	1*	15	9	6
ENII/MN Trans & MN	6	13	1	10		5		33	5	5
LN	7	4	6	10	1	12	1*	23	10	13
Prepalatial		1		1				2	1	
Old/Neo-Palatial	1			1				6	1	
Final Palatial								3		

MinAU of non-pathological specimens											
	PE	Fp	MCp	MCd	MTp	MTd	MPp	MPd	PH1	PH2	PH3
Aceramic	1		3	2	1				7	4	5
ENIa	3		3		2	2			8	5	1
ENIb	21	4	19	11	13	8		6	51	49	30
ENIc-ENII	45	13	64	54	48	45	1	6	129	110	74
ENII/MN Trans & MN	82	24	77	48	74	60	2	6	183	160	151
LN	100	37	118	41	102	67	1	11	345	310	316
Prepalatial	25	9	25	16	16	9		9	60	41	27
Old/Neo-Palatial	11	25	15	15	24	16		9	89	63	27
Final Palatial	11	3	7	6	6	6		4	12	12	2

Table 7:5 Frequency of cattle pelves with eburnation by sex and sub-phase (MinAU).

	Sex	Aceramic	ENIa	ENIb	ENIc-ENII	ENII/MN Trans & MN	LN	Pre-palatial	Old-Neopalatial	Final Palatial
Non pathological	Indeterminate	1	1	4	14	29	27	12	6	1
	♀		1	13	21	34	56	7	5	5
	♂		1	3	5	14	9	2		4
	?♀			1	5	4	6	1		
	?♂					1	2	3	1	1
Patho-logical	Indeterminate						1		1	
	♀		1	2	1	5	6			
	♂					1				

7.4.4 Conclusion

Neolithic cattle seem to have been managed as multi-purpose animals, at least from ENII onwards: adult females were kept for breeding and traction and, ultimately, were eaten; most males were killed at a younger age and so were apparently reared for their meat. During the course of the Neolithic, the size of cattle decreases and this may be accounted for by the apparent selective slaughter of young males; this will have minimised reproductive competition between males and so neutralised selective pressure for large body size, while selective pressure for smaller body size may have been caused by restrictions on the grazing movements of domestic livestock.

Increasing proportions of adult cattle and improved male survivorship in BA contexts are consistent with a more specialised traction strategy using oxen. The incidence of pathologies, however, offers no support for this interpretation. An alternative possibility is the rearing of very large adult male cattle for prestige feasting events. Hints of a slight increase in overall body-size, perhaps reflecting the breeding of more powerful animals, are consistent with both interpretations and thus with the FP textual evidence, to be discussed below, for plough teams sponsored by the palace.

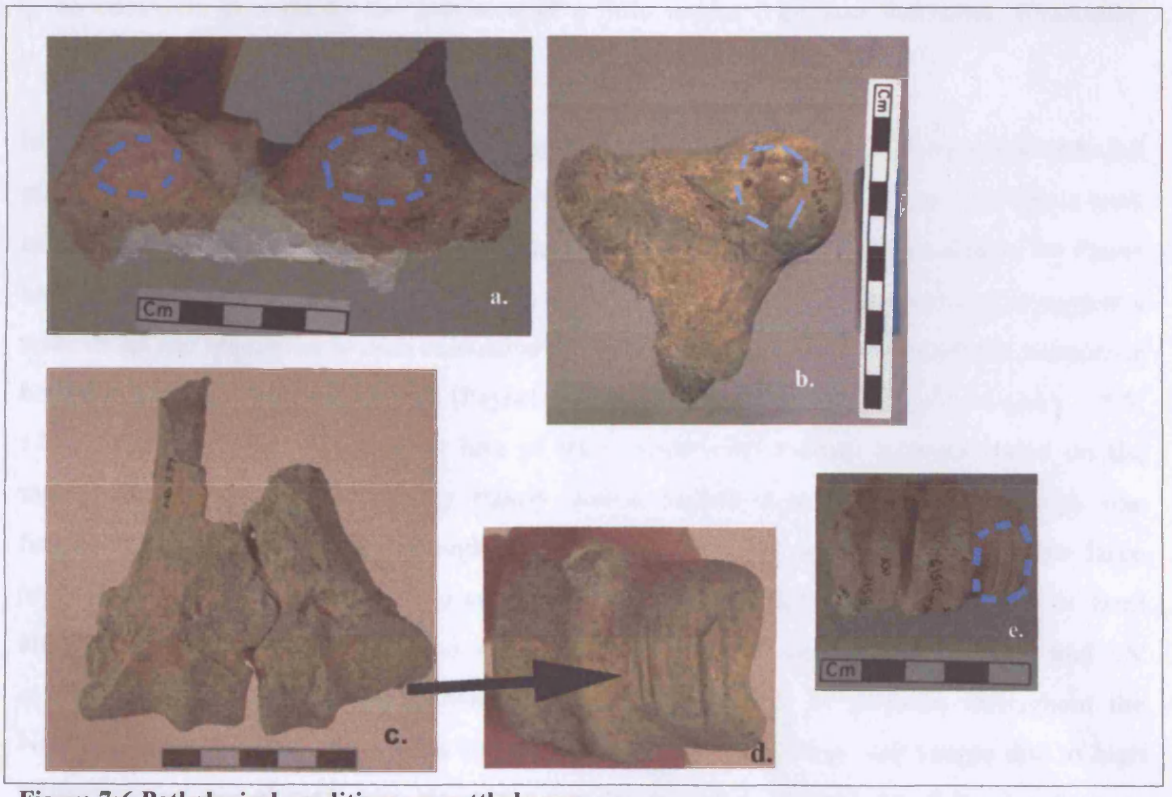


Figure 7:6 Pathological conditions on cattle bones
a) Eburnation on acetabula (WC, ENIc context); b) eburnation on femur head (MN context); c) extended condyles and exostosis on metacarpal (WC, ENII context); d) detail of (c) showing eburnation and grooving of condyle; e) grooving on condyle of metacarpal (PEM, EMIII context).

7.5 Pig management

7.5.1 Distinct populations and body-size changes?

For the first three sub-phases, the paucity of measurements makes it impossible to determine whether a size decrease occurred in pigs. For the astragalus, which is less sexually dimorphic than forelimb body parts (Bull and Payne 1988: 30), a few Aceramic-ENIa specimens fall outside the domestic range from other sites (Table 7:6). Otherwise, the bulk of the measurements from all sub-phases falls within similar ranges, which at other sites have been identified as representing domesticates. On present evidence, therefore, we cannot argue for size decrease through the Neolithic and BA, unlike what has been suggested above for cattle. It is possible that pigs were herded in a different manner to cattle: in the absence of predators, the animals may have been allowed to forage in the wild and were perhaps penned only at particular times of the year, or day, depending on their age and sex. This would have allowed these animals to achieve higher nutritional levels compared to more closely herded or yard-reared animals and thus to have avoided selection for smaller bodied individuals. Similar practices can be observed at present around the Mediterranean, with pigs herded in forested areas, where they are allowed to roam during the day (Isaakidou fieldnotes Sicily, Madonie Mts) and enticed back to an enclosure at night by the provision of a little fodder (Halstead fieldnotes, Chalkidiki, northern Greece).

In addition, for sub-phases with larger samples of measurements, some specimens both fall outside known domestic ranges *and* cover a wide range (Figure 7:7 and Figure 7:8). These were assessed by calculating Pearson's coefficient of variation (hence CV), as suggested by Payne and Bull (1988) and Rowley-Conwy (1995). High CVs for MN and LN measurements suggest a wide range and are similar to ones calculated for western Mediterranean assemblages containing both domestic and wild individuals (Payne and Bull 1988; 65, table 7; Rowley-Conwy 1995: 122-3, figs. 8 and 9). There is no hint of such animals in Palatial contexts based on the measurements, which cluster fairly tightly within known domestic ranges, although one fragmentary mandible is large enough to derive from a feral animal. There are also large 'outliers' in ENIc-ENII (radius Bp) and Prepalatial (astragalus GLl). The presence of feral animals is supported by the age and sex compositions of the sub-assemblages. MN and LN assemblages are dominated by females, and the vast majority of animals, throughout the Neolithic and Prepalatial periods, is culled 2.5 years old. Thus, large size ranges due to high proportions of old animals and big males can be excluded. Indeed, the Palatial sub-phase measurements which have the lowest CV value, show both a higher frequency of males and older animals than previous sub-phases.

In conclusion it is suggested that, at least in the MN-LN and possibly from ENII onwards, feral populations may have been established, which were exploited by the inhabitants of Knossos[4]. Metrical evidence, however, suggests that such feral animals made only a small contribution to the pig assemblages from these phases and so do not undermine the use of mortality data to explore pig management.

Table 7:6 Selected comparative measurement ranges for pigs (mm.; black: pig; grey: boar; data sources as listed in Table 7:1, except Youra: Trandalidou 2003: 168, table 11:27).

		GLp	LG	BG	SLC	Bp	Bd	GLl	GLm
Youra	Scapula				17.0				
	Humerus						34.1		
	Astragalus						22.4-25.9	40.4-40.9	36.8-38.2
LN Makriyialos	Scapula	27.0-41.0		12.0-28.0					
	Humerus						30.0-42.0		
	Radius					22.0-34.0			
	Tibia						25.0-36.0		
	Astragalus							34.0-44.0	30.0-39.0
LN Phaistos	Scapula	32.0-41.8	26.1-36.8	19.0-29.9	18.0-28.1				
	Humerus						36.5-44.9		
	Radius					26.3-33.2			
	Tibia						27.8-30.6		
	Astragalus							33.5-44.1	30.8-39.3
LN Dhimini	Scapula								
	Humerus						35.5-40.0		
	Radius								
	Tibia						26.5-27.0		
LN Aghia Sophia	Humerus						35.0-39.5		
	Radius					23.6-28.0			
	Tibia								
	Astragalus							38.5-45.0	
FN-MB Pefkakia	Scapula		23.0-30.5	18.0-25.5					
	Humerus					22.5-32.0	32.0-42.0		
	Tibia						25.0-31.5		
	Astragalus							33.5-43.0	
EH-LH Tiryns	Scapula	28.0-38.0			19.0-25.0				
	Humerus			18.0-25.0			29.0-42.0		
	Radius					21.0-32.0			
	Astragalus							28.0-44.0	30.0-40.0
EH-LH Lerna	Scapula				17				
	Humerus						40		

[4] The possibility that feral pigs were present in the Neolithic at Knossos is also suggested by Pérez Ripoll, but due to the preliminary character of his article, no precise data are presented in support of the argument (Pérez Ripoll 2002: 150-1).

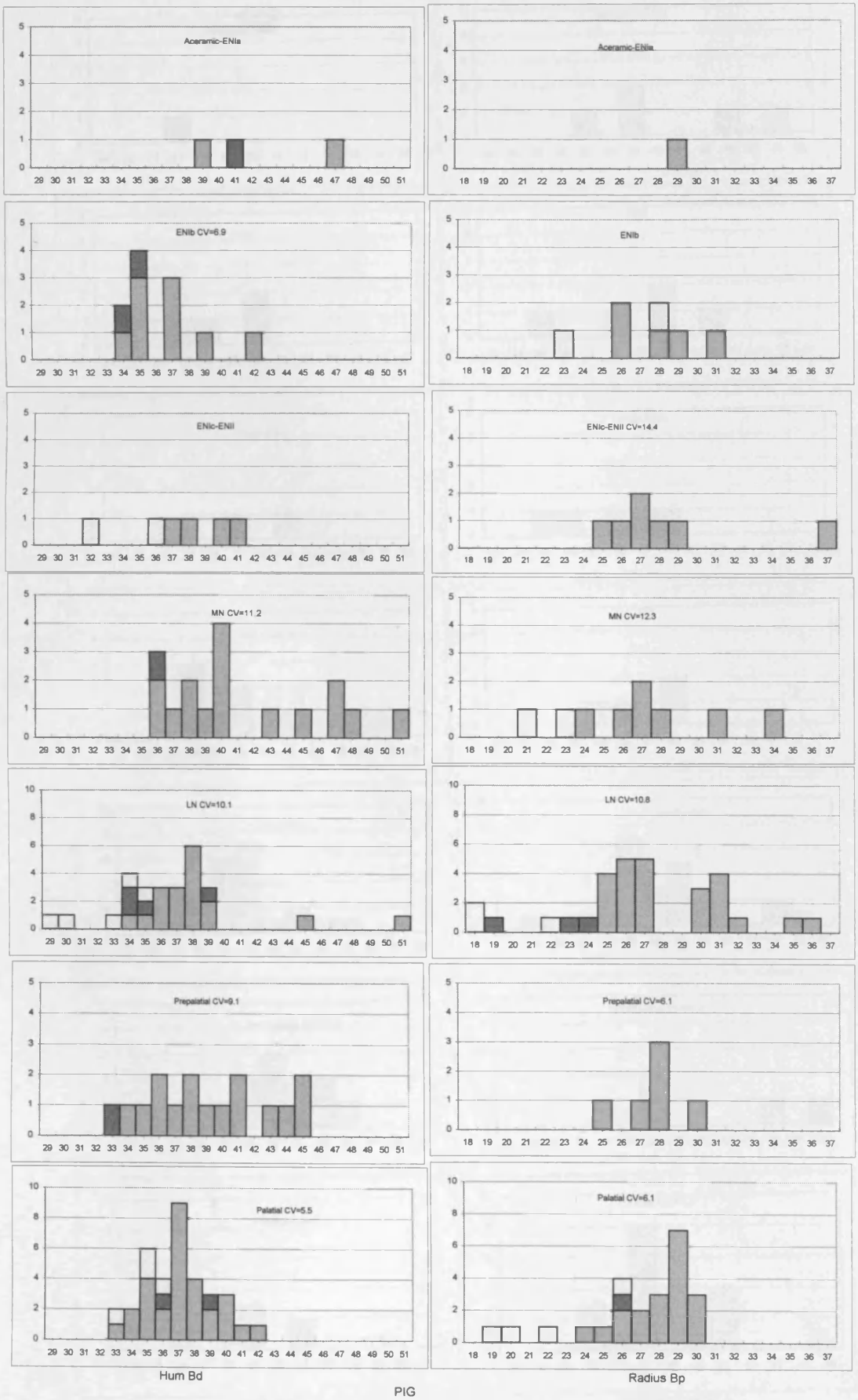


Figure 7:7 Grouped Frequency Distribution histograms for pig humerus (Bd) and radius (Bp) (white: unfused; grey: fused; dark grey: fusing)

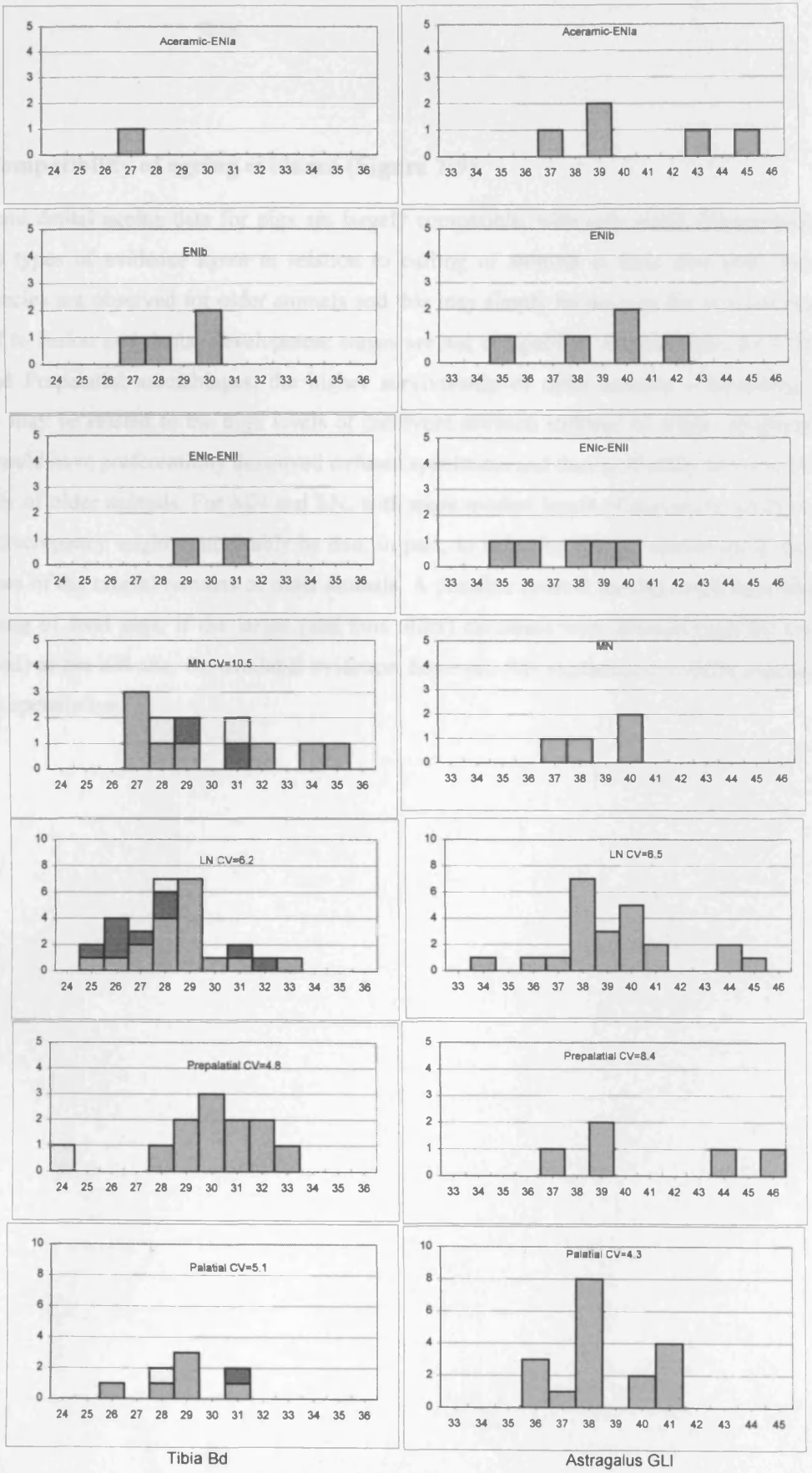


Figure 7:8 Grouped Frequency Distribution histograms for pig tibia (Bd) and astragalus (GLl) (white: unfused; grey: fused; dark grey: fusing)

7.5.2 Compatibility of ageing evidence (Figure 7:9)

Fusion and dental ageing data for pigs are largely compatible, with only slight discrepancies. The two types of evidence agree in relation to culling of animals in their first year. More discrepancies are observed for older animals and this may simply be because the absolute ages assigned to fusion and dental development stages are not compatible. Alternatively, for ENIc-ENII and Prepalatial assemblages, the higher survivorship of older animals – according to fusion – may be related to the high levels of carnivore attrition suffered by these sub-groups, which would have preferentially destroyed unfused specimens and thus artificially increased the frequency of older animals. For MN and LN, with more modest levels of scavenger attrition, a similar discrepancy might conceivably be due, in part, to selective discard elsewhere in these sub-phases of the cranial remains of older animals. A possible context for this might have been the hunting of feral pigs, if the larger (and thus older) carcasses were dressed (and the head abandoned) at the kill-site. On available evidence, however, this explanation must be regarded as *highly* speculative.

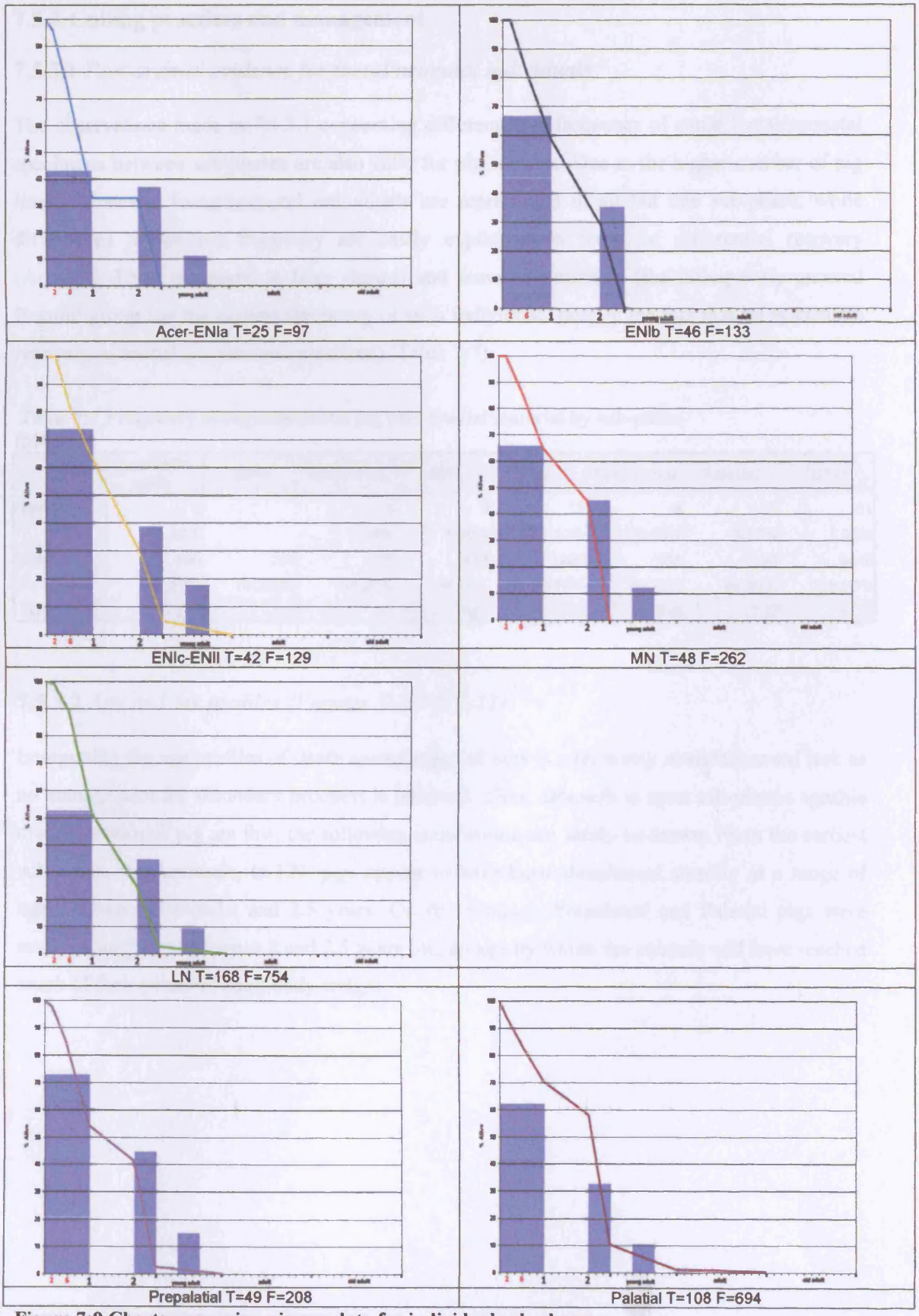


Figure 7:9 Charts comparing pig age data for individual sub-phases (fusion: bars; mandibular tooth ageing: cumulative curves; MinAU; T=combined MinAU counts for loose teeth and mandibles; F=combined MinAU counts for all post-cranial material providing fusion information).

7.5.3 Culling practices and management

7.5.3.1 *Post-cranial evidence for foetal/neonatal individuals*

The observations made in 7.4.3.1 concerning differences in frequency of cattle foetal/neonatal specimens between sub-phases are also valid for pig remains. Due to the higher number of pig litters, however, foetal/neonatal individuals are represented in all but one sub-phase, while differences in relative frequency are easily explicable in terms of differential recovery (Aceramic-ENIa compared to later phases) and scavenger attrition (the infrequently gnawed Palatial group has the highest frequency of such individuals despite the fact that no systematic recovery of faunal remains was practised) (Table 7:7).

Table 7:7 Frequency of foetal/neonatal pig post-cranial material by sub-phase (MinAU).

	Aceramic-ENIa	ENIb	ENIc-ENII	MN	LN	Prepalatial	Palatial	TOTAL
New-Born	5		6	9	19	4	38	81
	2.50%		1.80%	1.90%	1.30%	0.80%	3.10%	1.80%
Older	199	288	325	473	1483	481	1199	4448
	97.50%	100.00%	98.20%	98.10%	98.70%	99.20%	96.90%	98.20%
TOTAL	204	288	331	482	1502	485	1237	4529

7.5.3.2 *Age and sex profiles (Figures 7: 10 & 7:11)*

Interpreting the age profiles of death assemblages of pigs is a relatively straightforward task as no management for secondary products is involved. Thus, although in most sub-phases ageable dental remains of pig are few, the following conclusions can safely be drawn. From the earliest sub-phase, the Aceramic, to LN, pigs appear to have been slaughtered steadily at a range of ages, between 2 months and 2.5 years. On the contrary, Prepalatial and Palatial pigs were mostly slaughtered between 2 and 2.5 years old, an age by which the animals will have reached much of their potential adult body weight.

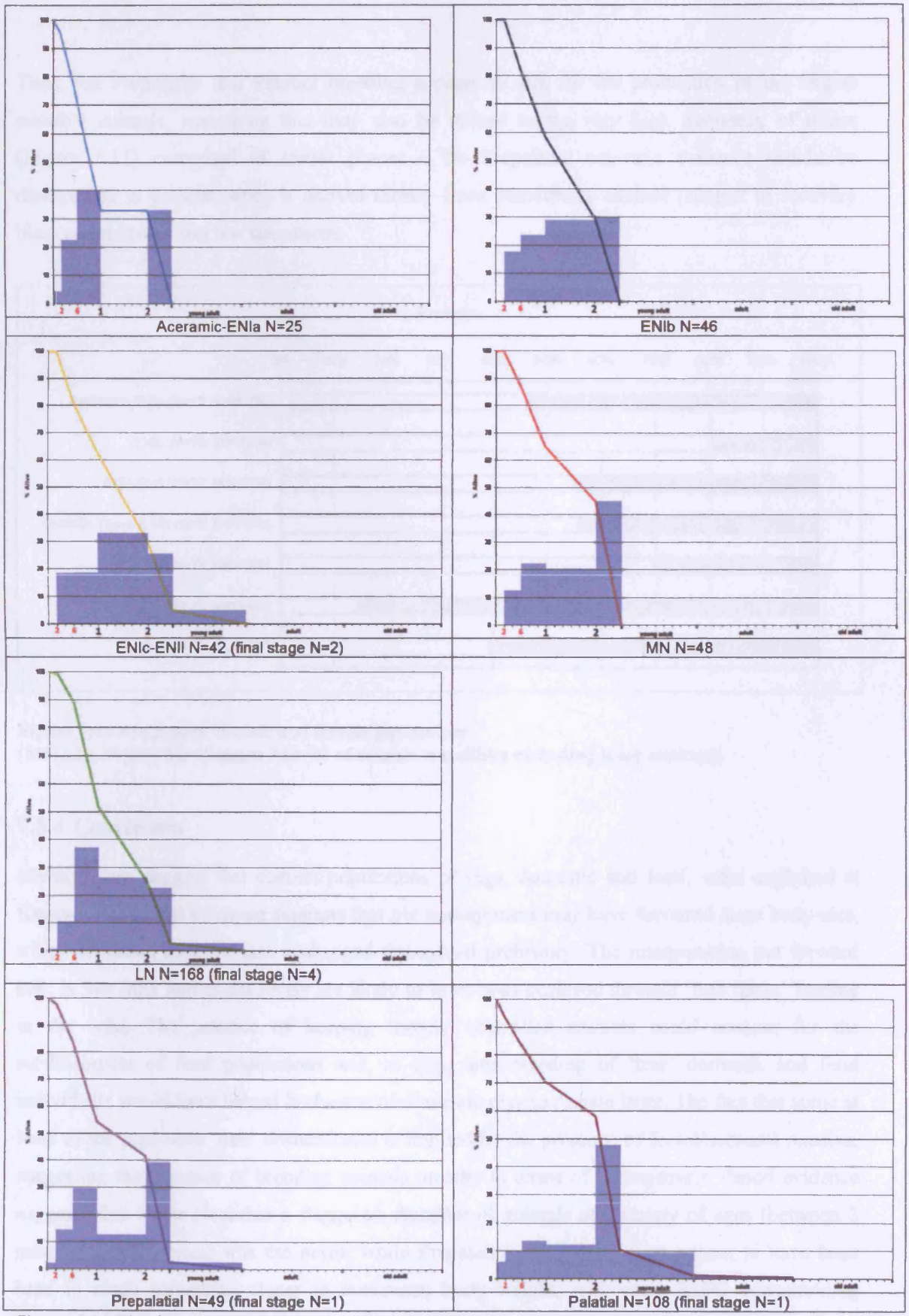


Figure 7:10 Pig: Survivorship curves combined with histograms showing percentage of deaths for each age stage
(N=combined MinAU counts for loose teeth and mandibles).

Thus, the Prepalatial and Palatial breeding appears to aim for the production of the largest possible animals, something that may also be related to the very high frequency of males (Figure 7:11) compared to earlier phases – the Prepalatial sex-ratio evidence should be disregarded at present, since it derives mostly from mandibular canines (subject to recovery bias) and relies on too few specimens.

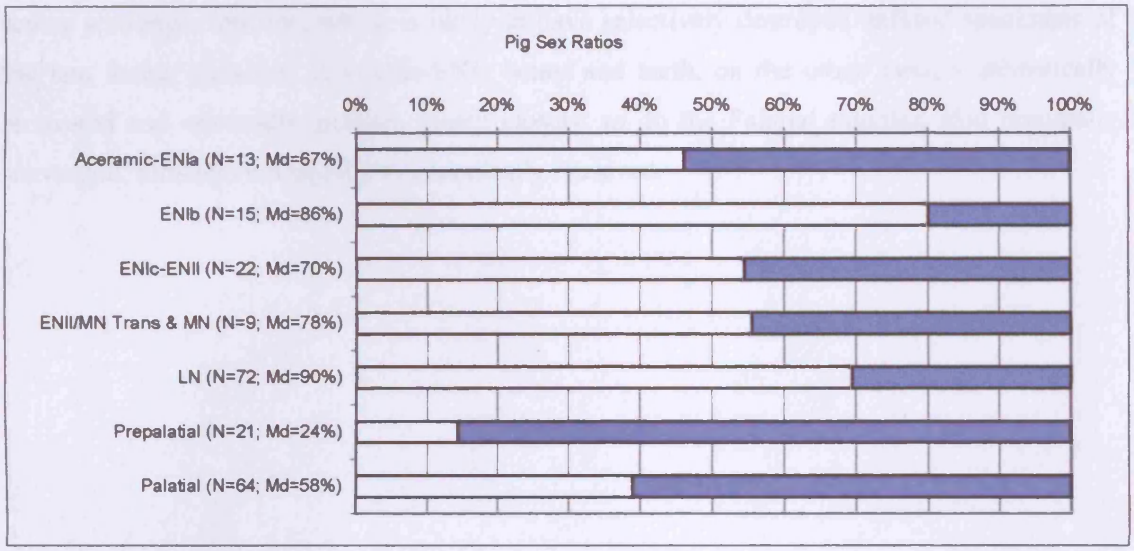


Figure 7:11 Frequency of male and female pig canines
(MinAU; N=number of cases; Md=% of sexable mandibles excluding loose canines).

7.5.4 Conclusion

Metrical data suggest that distinct populations of pigs, domestic and feral, were exploited at Knossos. Available evidence suggests that pig management may have favoured large body-size, which remained more or less unchanged throughout prehistory. The interpretation put forward here is that high nutritional levels are likely to have been achieved through 'free range' feeding in the wild. The practice of keeping loosely controlled animals could account for the establishment of feral populations and, in turn, inter-breeding of 'true' domestic and feral individuals would have helped body-size of domestic pigs to remain large. The fact that some at least of the pigs were 'true' domesticates is implied by the presence of foetal/neonatal remains, suggesting the presence of breeding animals on-site. In terms of management, dental evidence suggests that in the Neolithic a staggered slaughter of animals at a variety of ages (between 2 months and 2.5 years) was the norm, while Prepalatial and Palatial pigs appear to have been bred to reach something closer to maximum body weight, with most deaths concentrating around 2-2.5 years and a larger percentage of older animals and males being kept than previously.

7.6 Ovicaprid management

7.6.1 Compatibility of ageing evidence (Figure 7:12)

This section begins with an assessment of the compatibility of post-cranial fusion and dental ageing data, of necessity for sheep and goat combined, because unfused post-cranial specimens are often not identifiable to species. The two datasets are largely compatible, and differences can be attributed to post-depositional processes: ENIb-ENII sub-assemblages have suffered severe scavenger attrition, which is likely to have selectively destroyed unfused specimens of the late fusing elements; Aceramic-ENIa bones and teeth, on the other hand, systematically recovered and minimally gnawed, match closely, as do the Palatial samples, also minimally scavenged, although not equally systematically retrieved.

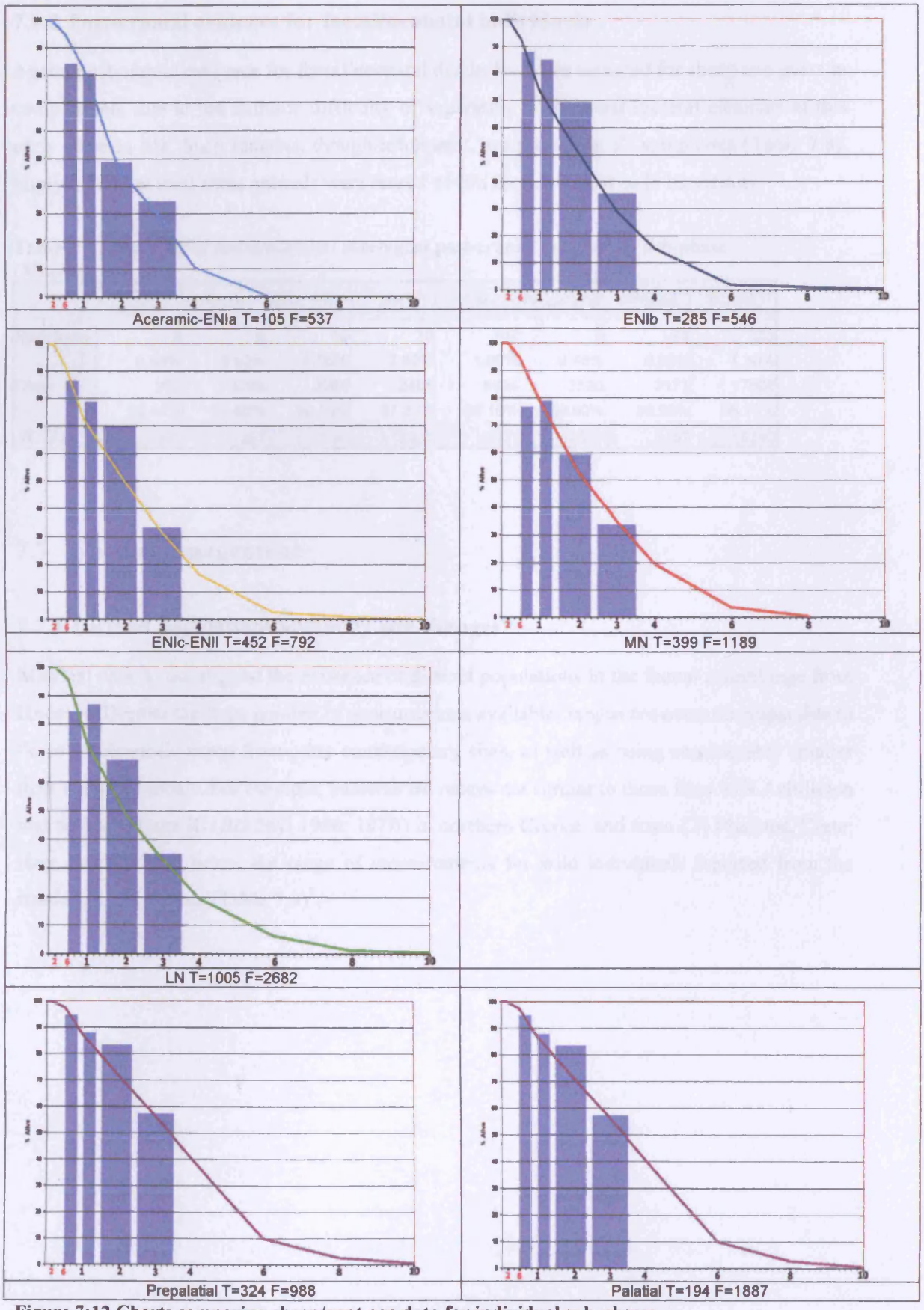


Figure 7:12 Charts comparing sheep/goat age data for individual sub-phases (fusion: bars; mandibular tooth ageing: cumulative curves; MinAU; T=combined MinAU counts for loose teeth and mandibles; F=combined MinAU counts for all post-cranial material providing fusion information)

7.6.2 Post-cranial evidence for foetal/neonatal individuals

Again, post-cranial evidence for foetal/neonatal deaths has to be assessed for sheep and goats in combination, due to the extreme difficulty of separating post-cranial skeletal elements at this early stage in life. Such remains, though infrequent, are present in all sub-phases (Table 7:8), implying that at least some animals were reared within the settlement or in its vicinity.

Table 7:8 Frequency of foetal/neonatal sheep/goat post-cranial material by sub-phase (MinAU).

	Aceramic-ENIa	ENIb	ENIc-ENII	MN	LN	Prepalatial	Palatial	TOTAL
New-Born	9	6	18	70	107	9	16	235
	0.90%	0.50%	0.90%	2.80%	1.90%	0.40%	0.50%	1.30%
Older	982	1255	2085	2461	5424	2530	3171	17908
	99.10%	99.50%	99.10%	97.20%	98.10%	99.60%	99.50%	98.70%
TOTAL	991	1261	2103	2531	5531	2539	3187	18143

7.7 Sheep management

7.7.1 Distinct populations and body size changes?

Metrical data do not suggest the existence of distinct populations in the faunal assemblage from Knossos. Despite the large number of measurements available, ranges are overall comparable to those for domestic sheep from other contemporary sites, as well as being considerably smaller than wild individuals. For example, humerus Bd ranges are similar to those from MN Achilleion and Sitagroi II and III (Bökönyi 1986: 107ff) in northern Greece, and from LN Phaistos, Crete; they also fall well below the range of measurements for wild individuals reported from the Iranian site of Bastam (Table 7:9)[5].

[5] Wild sheep metrical data are not available from Greek sites, as the area is well outside the natural distribution of the species.

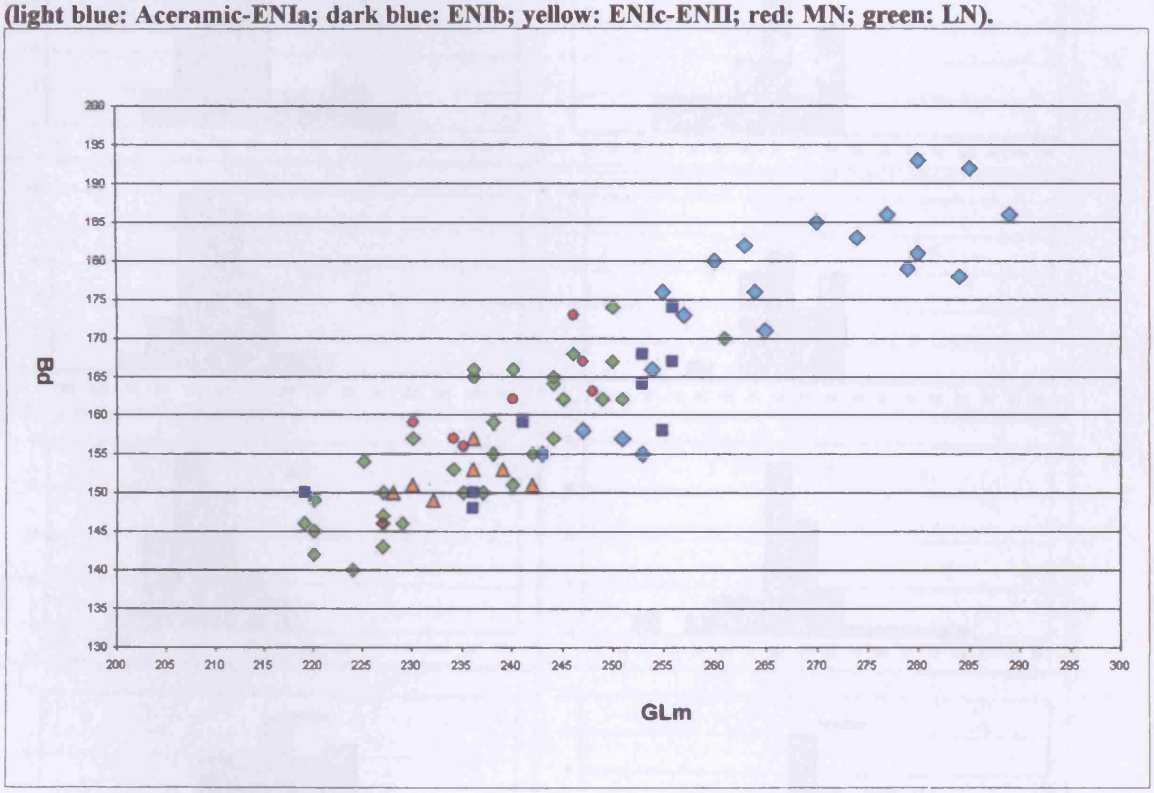
Table 7:9 Selected comparative measurement ranges for sheep (mm.; black: domestic; grey: wild; *: approximate values; data sources as listed in Table 7:1, apart from Achilleion, Bastam and Tsoungiza, listed at the end of the table).

		GLp	LG	BG	SLC	Bp	Bd	GLl	GLm
		MN							
Bastam	Humerus						36.0-42.5*		
Achilleion	Humerus						25.5-31.5*		
Sitagroi	Humerus						23.0-32.0		
		LN							
Makriyialos	Scapula	27.0-36.0		16.0-24.0					
	Radius					23.0-32.0			
	Metacarpal						21.0-25.0		
	Tibia						20.0-27.0		
	Astragalus						15.0-19.0	24.0-30.0	22.0-28.0
Phaistos	Scapula	25.8-29.0	20.9-24.0	17.4-19.3	16.7-17.8				
	Humerus						24.4-30.0		
	Radius					24.0-27.2			
	Metacarpal						20.9		
	Astragalus							22.7-23.5	21.9-23.0
	Metatarsal						21.1		
		FN-EH							
Tsoungiza	Scapula	30.0-35.8		18.5-22.9					
	Humerus						32.2		
	Radius					30.1-37.8	31.4		
	Metacarpal						26.9		
	Metatarsal						24.2		
		EH-LH							
Tiryns	Scapula	27.0-37.0		17.0-27.0					
	Radius					26.0-42.0	24.0-37.0		
	Metacarpal						22.0-29.0		
	Metatarsal						20.0-28.0		
Lerna	Scapula	30.0							
	Humerus						27.0-36.0		
	Radius					30.0-34.0	27.0-32.0		
	Metacarpal						24.0-29.0		
	Metatarsal						23.0-24.0		
References	Achilleion	Bökönyi 1989: 328							
	Bastam	Krauss 1975, table 39e, in Benecke 1998: 177, fig. 6							
	Tsoungiza	Halstead *in pressb*							

Body-size decrease is plainly evident in Knossian sheep through the Neolithic. It is observable on a number of measurements (Figure 7:14 and 7:15). To an extent, such differences might be attributable to sexual dimorphism and changing sex ratios, but two types of evidence suggest that they do not simply reflect lower ratios of large male to smaller female animals in successive sub-phases of the Neolithic. First, the ENIb sheep and their, on average, smaller ENIc counterparts, are mostly females (Figure 7:18); secondly, the pattern is unambiguous for astragalus, which exhibits relatively low sexual dimorphism (Figure 7:13). Interpretation of the metrical evidence from the Aceramic-ENIa sub-phase, however, is not as straightforward. The

animals appear to be on average larger than in later phases but the sex ratios show equal numbers of adult males and females (Figure 7:18), raising the possibility that the apparently larger size is mainly an effect of a greater number of adult males in the sample. On the other hand, the sample of sexable pelves is small and therefore not necessarily reliable, thus preventing a firm conclusion at present. Conversely, the increase observed in BA contexts can be more economically attributed to the increased survival of adult males, as evidenced by sexable pelves. This pattern fits in with the textual evidence from the later phases of the BA for palatial involvement in the management of wool flocks which consisted mostly of castrated males.

Figure 7:13 Scatterplot of astragalus GLm-Bd measurements of sheep (light blue: Aceramic-ENIa; dark blue: ENIb; yellow: ENIc-ENII; red: MN; green: LN).



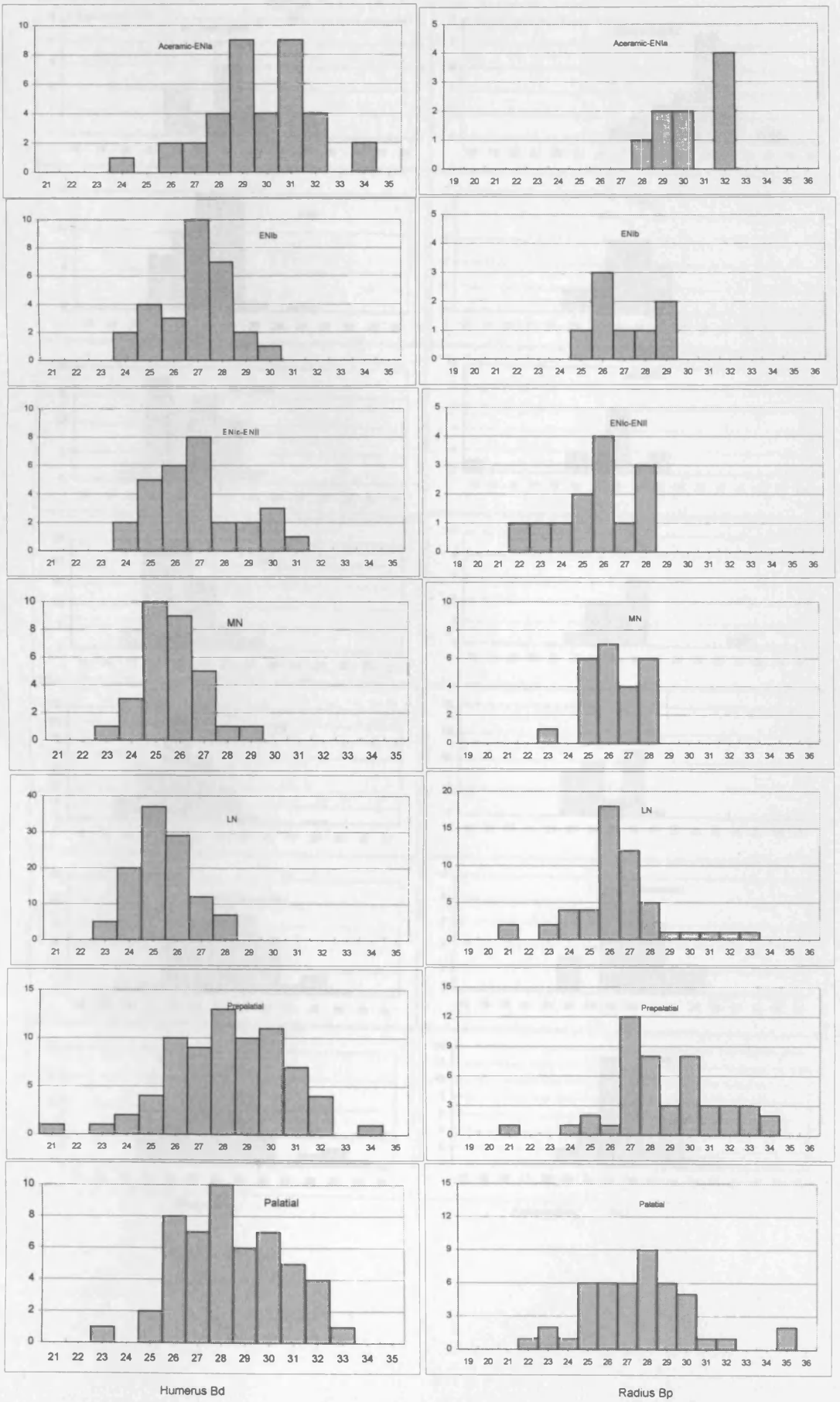


Figure 7:14 Grouped Frequency Distribution histograms for sheep humerus (Bd) and radius (Bp) (white: unfused; grey: fused; dark grey: fusing)

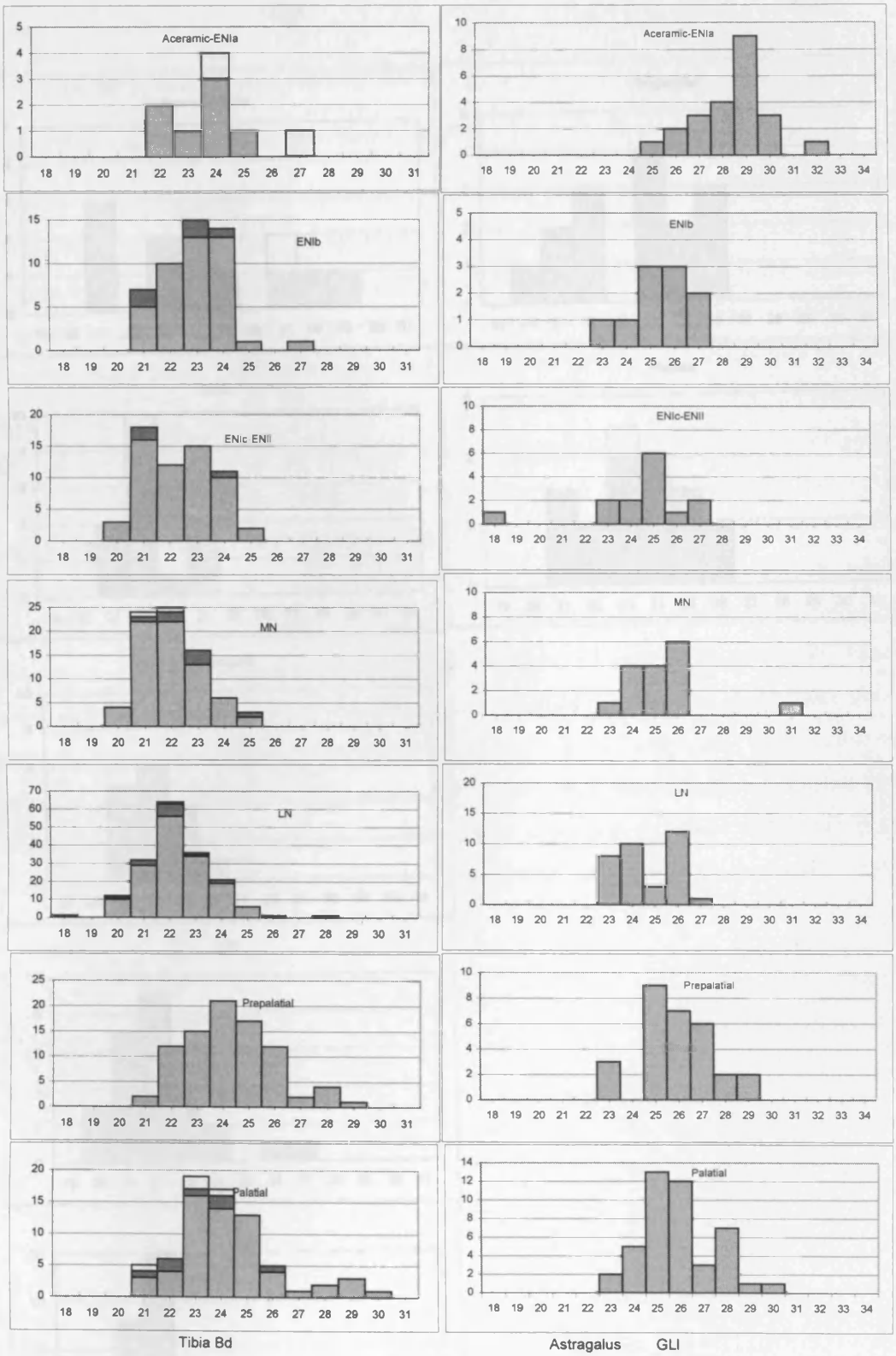


Figure 7:15 Grouped Frequency Distribution histograms for sheep tibia (Bd) and astragalus (GLl) (white: unfused; grey: fused; dark grey: fusing)

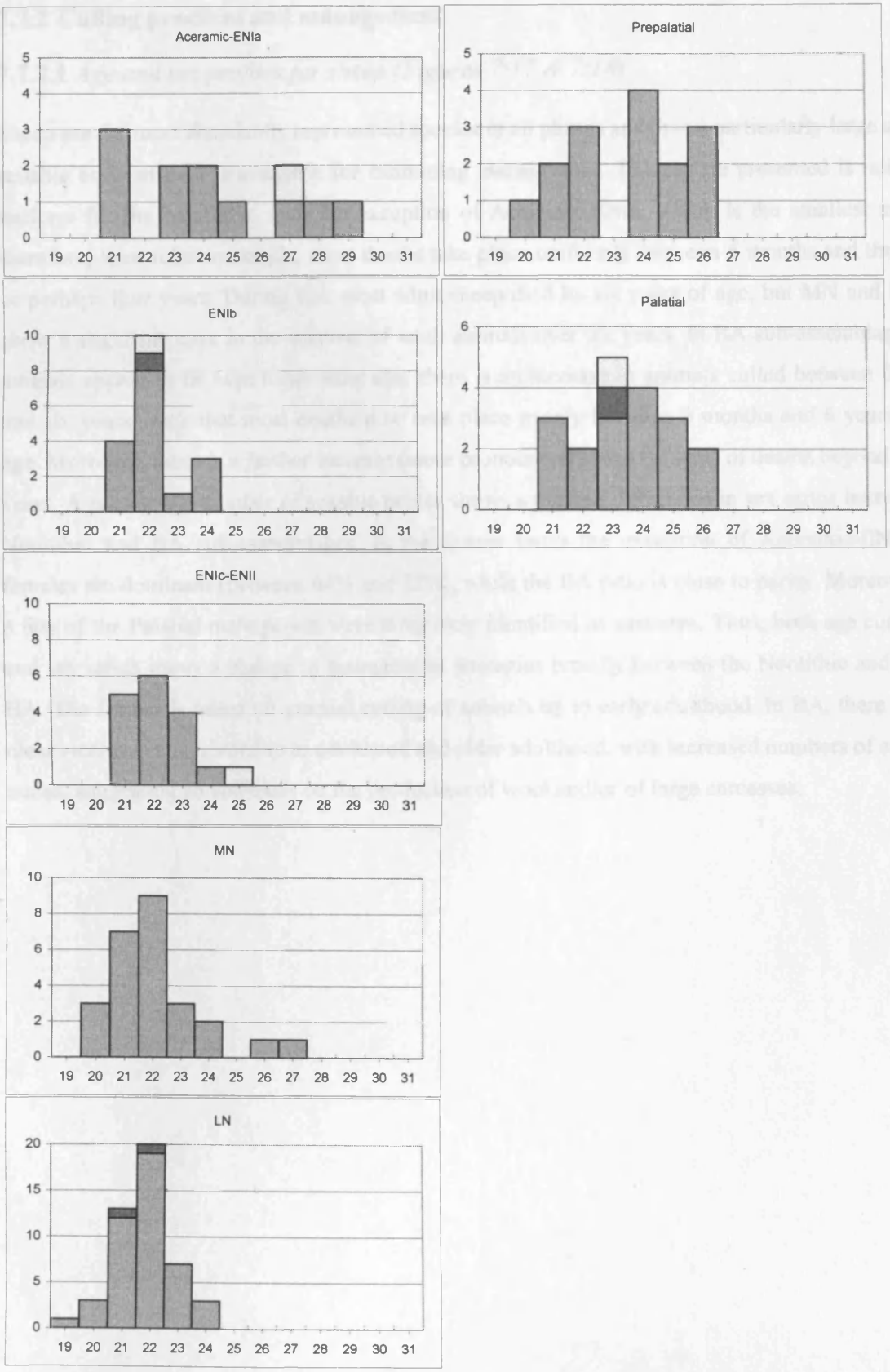


Figure 7:16 Grouped Frequency Distribution histograms for sheep metacarpal (Bd) (white: unfused; grey: fused; dark grey: fusing)

7.7.2 Culling practices and management

7.7.2.1 *Age and sex profiles for sheep (Figures 7:17 & 7:18)*

Sheep are the most abundantly represented species in all phases and thus a particularly large and reliable body of data is available for examining management. The picture presented is rather uniform for the Neolithic: with the exception of Aceramic-ENIa, which is the smallest and, therefore, least reliable sample, most deaths take place uniformly between 6 months and three, or perhaps four years. During EN, most adult sheep died by six years of age, but MN and LN show a slight increase in the survival of adult animals over six years. In BA sub-assemblages, animals appear to be kept to an older age: there is an increase in animals culled between four and six years, such that most deaths now take place evenly between 6 months and 6 years of age. Moreover, there is a further increase (more pronounced in the Palatial) of deaths beyond six years. A reasonable number of sexable pelves shows a marked difference in sex ratios between Neolithic and BA sub-assemblages. In the former (with the exception of Aceramic-ENIa), females are dominant (between 64% and 82%), while the BA ratio is close to parity. Moreover, a few of the Palatial male pelves were tentatively identified as castrates. Thus, both age curves and sex ratios imply a change in management strategies broadly between the Neolithic and the BA. The former is based on gradual culling of animals up to early adulthood. In BA, there is a clear increase in survivorship to adulthood and older adulthood, with increased numbers of adult males, suggesting an emphasis on the production of wool and/or of large carcasses.

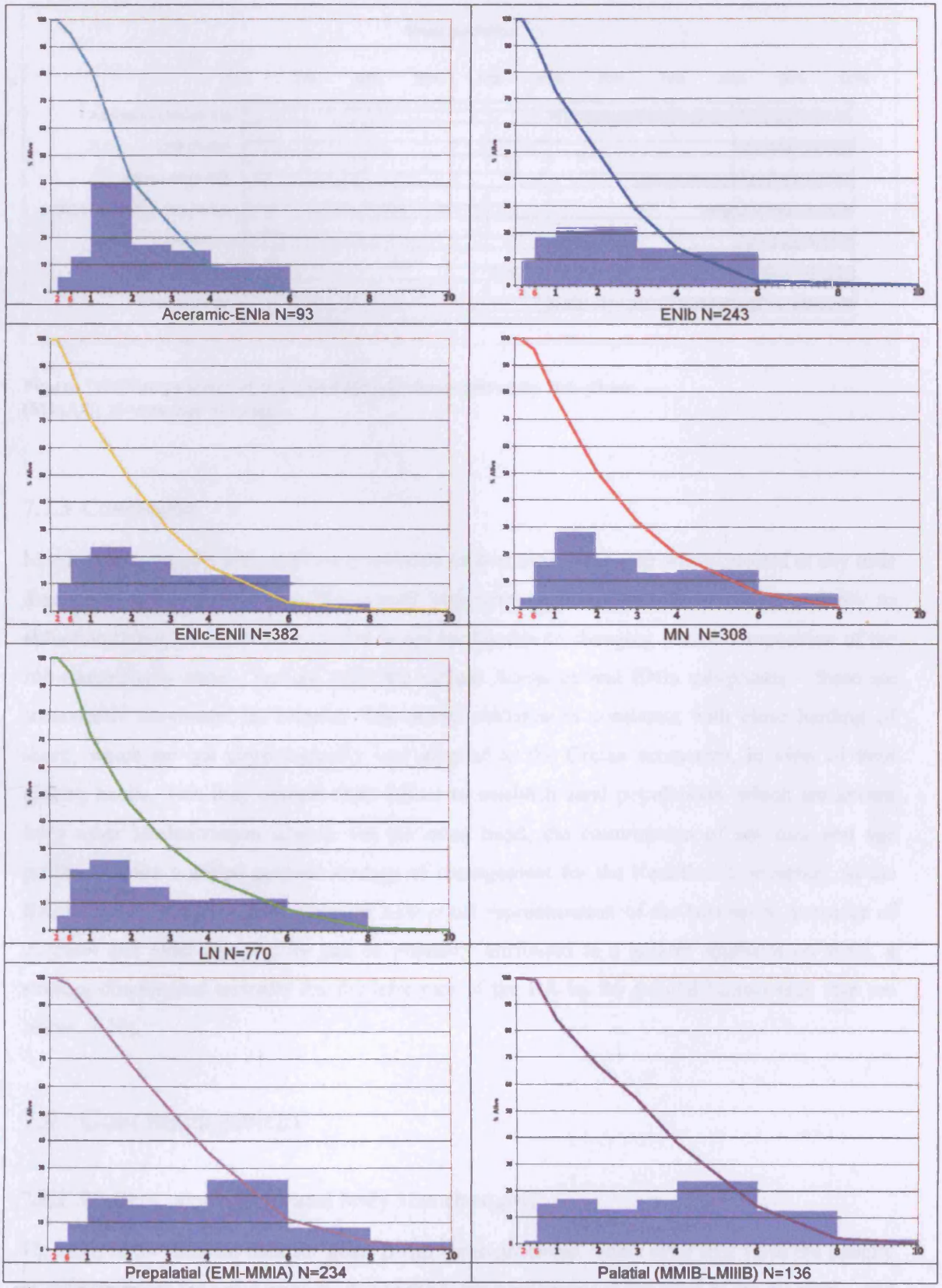


Figure 7:17 Sheep: Survivorship curves and histograms showing percentage of deaths for each age stage
(N=combined MinAU counts for loose teeth and mandibles).

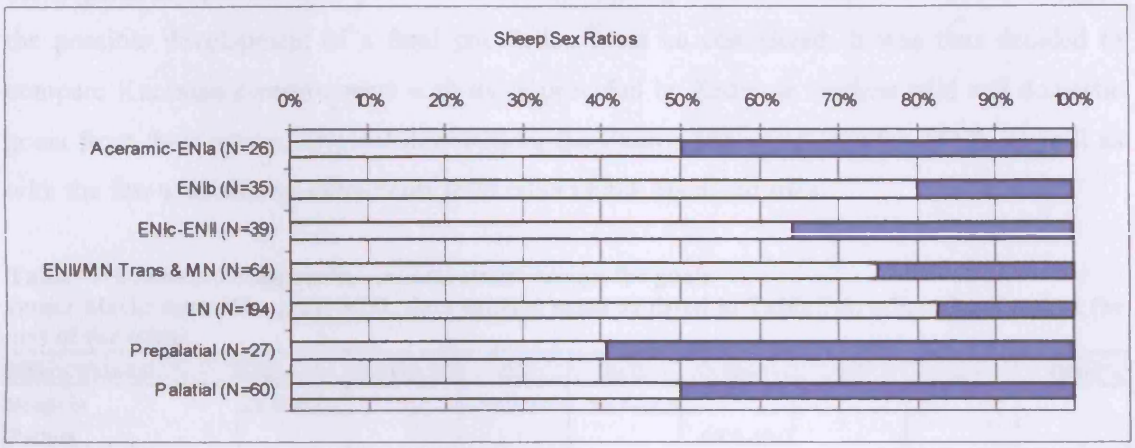


Figure 7:18 Frequencies of male and female sheep pelves by sub-phase (MinAU; N=number of cases).

7.7.3 Conclusion

Metrical data suggest that only one population of domesticated sheep was exploited at any time during prehistory at Knossos. The overall body-size of these animals shows a tendency to reduction through the Neolithic, which is not attributable to changing sexual composition of the sub-assemblages since – leaving aside the earliest Aceramic and ENIa sub-phases – these are consistently dominated by females. The above evidence is consistent with close herding of sheep, which are not physiologically best adapted to the Cretan ecosystem, in view of their grazing habits. This may explain their failure to establish feral populations, which are known from other Mediterranean islands. On the other hand, the combination of sex data and age profiles implies a mixed purpose strategy of management for the Neolithic. Conversely, in the BA, the increase in body-size coupled with equal representation of the two sexes, presence of castrates and older age profiles can be plausibly attributed to a greater emphasis on wool, a strategy documented textually for the later part of the BA by the palatial bureaucracy (but see below, 7.10).

7.8 Goat management

7.8.1 Distinct populations and body size changes?

The analysis of metrical data for goats poses some problems. These arise first from the paucity of measurements for some periods, due to the rarity of this species for most of the Neolithic, and secondly from the paucity of comparative data from other Greek sites. Many reports do not differentiate between sheep and goats, or they do so very conservatively, resulting in very small

sets of measurements. As the natural distribution of wild populations of goat does not include the Aegean, all remains are *de facto* considered to belong to domesticated individuals, but again the possible development of a feral population must be considered. It was thus decided to compare Knossian measurements with those provided by Zeder on *modern* wild and domestic goats from their area of original distribution, the Zagros Mountains (Zeder 2003), as well as with the few available measurements from other Greek mainland sites.

Table 7:10 Selected comparative measurement ranges for goats (mm.; black: domestic; grey: wild; data sources same as listed in Table 7:1, otherwise, listed at the end of the table).

Makriyialos LN	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Scapula	29.0-41.0		19.0-27.0	16.7-17.8				
Radius					26.0-40.0			
Metacarpal						26.0-37.0		
Tibia						23.0-30.0		
Astragalus						16.0-21.0	25.0-31.0	23.0-29.0
Metatarsal						22.0-28.0		
Aghia Sophia LN	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Humerus						26.5-36.5		
Radius					30.5-31.0	31.5		
Metacarpal						24.0-24.5		
Astragalus							27.5-30.5	25.5-28.0
Phaistos LN	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Scapula	28.0-40.4 39.9-43.0	23.1-32.1 34.0-37.3	17.0-26.8 29.8-32.7	16.0-18.0 26.4-28.0				
Humerus						29.0-35.0 40.8		
Radius					27.2-32.7 27.5-42.0			
Metacarpal						29.9-33.0 36.2		
Tibia						32.0-32.8		
Astragalus						18.0-20.8	29.0-29.8	27.9-28.1
Metatarsal						24.1-30.8		
Tiryns EH-LH	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Scapula	28.0-41.0		20.0-29.0					
Radius					26.0-38.0	27.0-31.0		
Metacarpal						23.0-34.0		
Tibia								
Astragalus						16.0-22.0	25.0-33.0	23.0-31.0
Lerna EH-LH	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Metacarpal						23.0-32.0		
Tsoungiza FN-EH	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Scapula	32.0-36.6		22.4-26.8					
Humerus						29.0-38.5		
Radius					36.5-37.8	31.0		
Metacarpal						29.5		
Astragalus						17.4-20.3	27.7-33.2	26.0-29.9
Modern wild population (Zagros Mts)	**GLp**	**LG**	**BG**	**SLC**	**Bp**	**Bd**	**GLl**	**GLm**
Humerus						24.5-34.0		
Tibia						23.5-31.5		
Metatarsal						22.5-31.0		
Reference	Zeder 2003: 128, fig. 2.							

In most cases, Knossian goats from all sub-phases combined cover the whole range of measurements from both domestic *and* wild examples cited by Zeder (2003). For the earlier phases of the Neolithic, measurements are rare, but those present are within the range of Zagros wild, while from MN onwards, specimens as large as or larger than modern wild goats exist among the goat remains at Knossos, based on comparisons for distal tibia and metatarsal breadth (Bd)[6]. It is difficult to interpret these conclusions for several reasons. First, there is considerable overlap between wild and domestic animals in Zeder's charts, apart from the largest wild males, possibly because of the small size of the sample – post-cranial elements of 40 individuals were measured, very few of which belonged to domestic individuals (Zeder 2003: 128, fig. 2). On the other hand, there is no information about the populations from which these animals were extracted, for example, whether they are isolated and of restricted numbers, so that the true potential range of body-size cannot be achieved, due to a reduced gene pool and/or restricted habitats. If any of the above apply, we might expect these modern wild animals to represent the lower end of the potential body-size range.

Finally, measurement ranges of Knossian goats are comparable with other Greek sites, and there is an overlap between the latter and the modern wild examples. There are two possible ways in which to explain this: either *domestic* goats were bred at high nutritional planes, in most sites and all phases of prehistory, enabling the maintenance of large body-size; or goat remains from mainland sites include *feral* animals which have not been recognised as such. For the time being, it is not possible to provide a conclusive answer to the question whether the Knossian remains from the larger end of the spectrum represent feral animals. An analysis of the measurements (i.e. calculation of CVs to establish the range of variation within populations) is not possible, as these are not presented in detail in Zeder's publication. It should be noted, however, that the left-skewed distributions of Neolithic measurements, together with the morphological sex data, suggest that most adult goats at Neolithic Knossos were female (Figure 7:19). Given the dramatic sexual dimorphism apparent in modern Greek goats, the large Neolithic goats from Knossos should, perhaps, be treated as domestic males. At least for the MN and LN assemblages, large body-size is not an effect of sexual composition, as these sub-phases are predominated by adult females (Figure 7:22). In terms of body-size, matters are complicated by the paucity of measurements in the earlier phases (Aceramic-ENII), making it difficult to establish whether any changes occurred during the Neolithic. No changes are

[6] Zeder provides data for four measurements, three of which are used here for comparison. Radius Bd is not used in the present study due to the rarity of measurable specimens; Humerus Dd, is considered to be a printing error and it is assumed that the chart presents humerus Bd measurements (Zeder 2003: 128, fig. 2).

observed from the MN to the Palatial, when several measurements are available: the bulk concentrate mostly in the same ranges (e.g., humerus and tibia Bd, Figure 7:20).

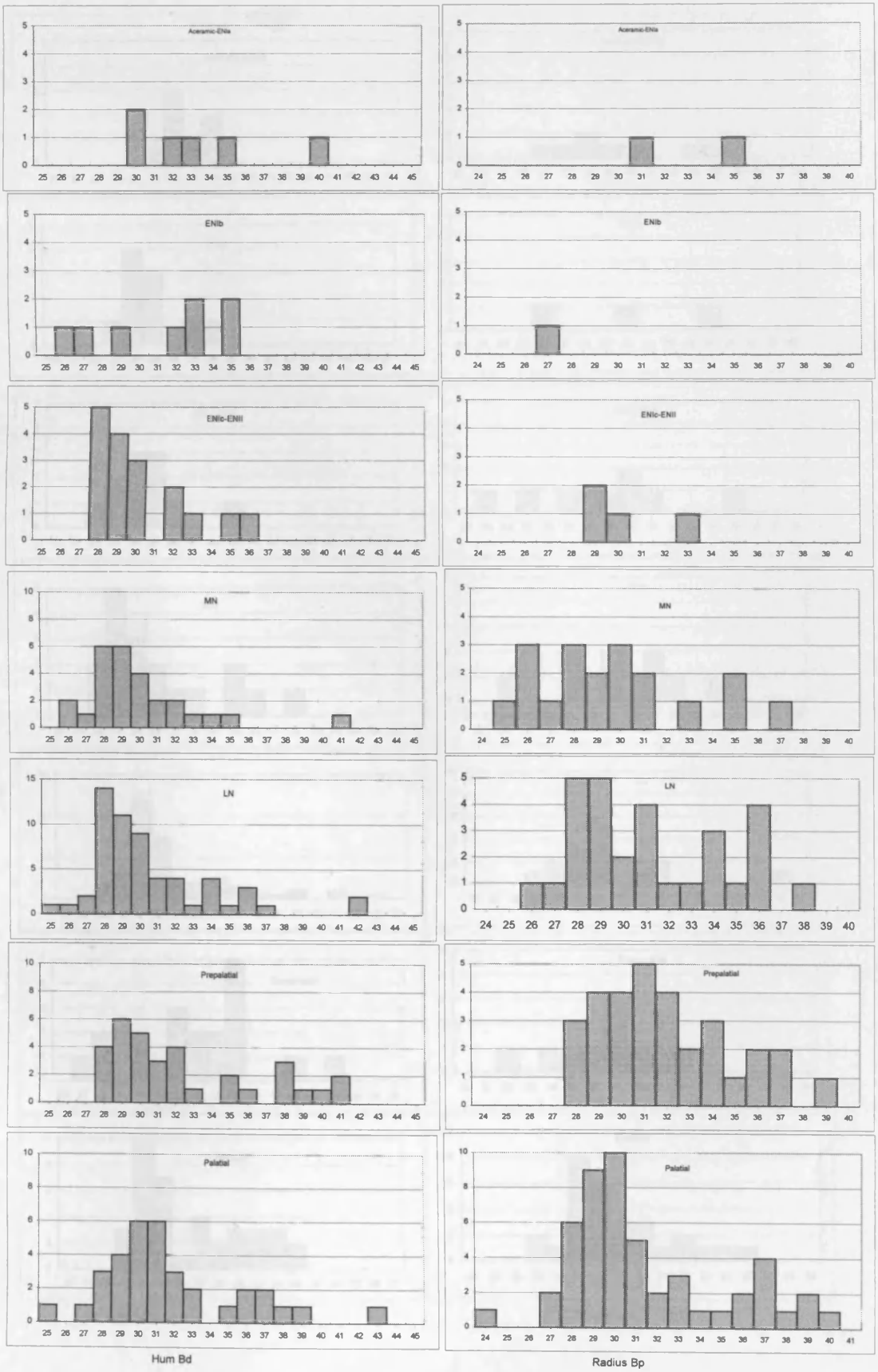


Figure 7:19 Grouped Frequency Distribution histograms for goat humerus (Bd) and radius (Bp) (white: unfused; grey: fused; dark grey: fusing)

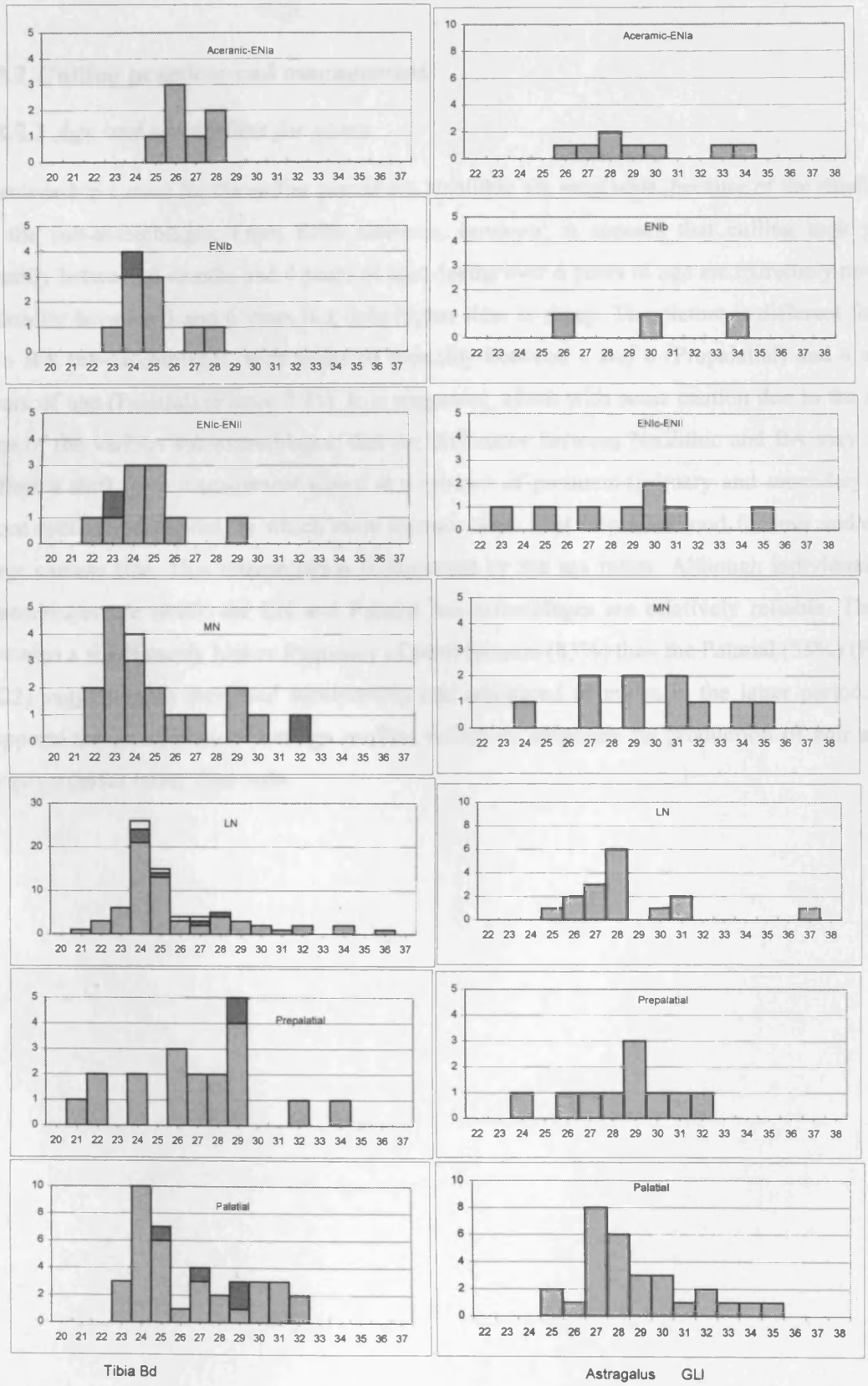


Figure 7:20 Grouped Frequency Distribution histograms for goat tibia (Bd) and astragalus (GLl) (white: unfused; grey: fused; dark grey: fusing)

7.8.2 Culling practices and management

7.8.2.1 *Age and sex profiles for goats*

Survivorship curves for the earlier part of the Neolithic are unreliable, because of the small size of the sub-assemblages. From ENIc onwards, however, it appears that culling took place steadily between 6 months and 4 years of age; deaths over 6 years of age are extremely rare but mortality between 3 and 6 years is a little higher than in sheep. The picture is different for the two BA sub-assemblages, with peaks of mortality between 4 and 6 (Prepalatial) and 4 and 8 years of age (Palatial) (Figure 7:21). It is suggested, albeit with some caution due to the small size of the various sub-assemblages, that the difference between Neolithic and BA may again reflect a shift from management aimed at a mixture of products (primary and secondary) to a more specialised regime, in which more animals were kept into adulthood for hair and/or for large carcass size. This interpretation is supported by the sex ratios. Although individual sub-assemblages are small, the LN and Palatial sub-assemblages are relatively reliable. The LN contains a significantly higher frequency of adult females (83%) than the Palatial (55%) (Figure 7:22) suggesting an increased survivorship into adulthood of males in the latter period. This supports the interpretation that age profiles reflect an emphasis on production of hair and/or large carcasses rather than milk.

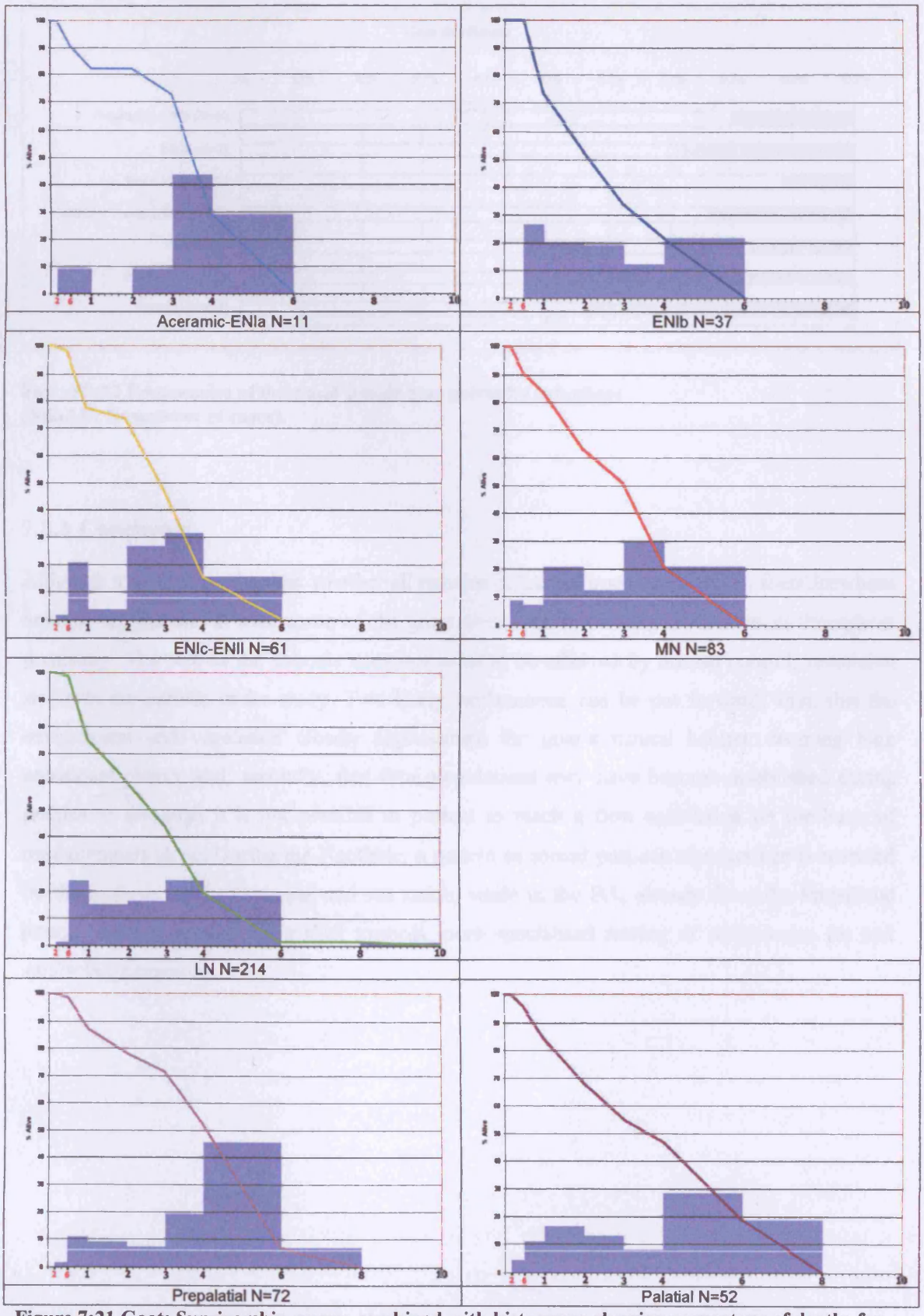


Figure 7:21 Goat: Survivorship curves combined with histograms showing percentage of deaths for each age stage
(N=combined MinAU counts for loose teeth and mandibles).

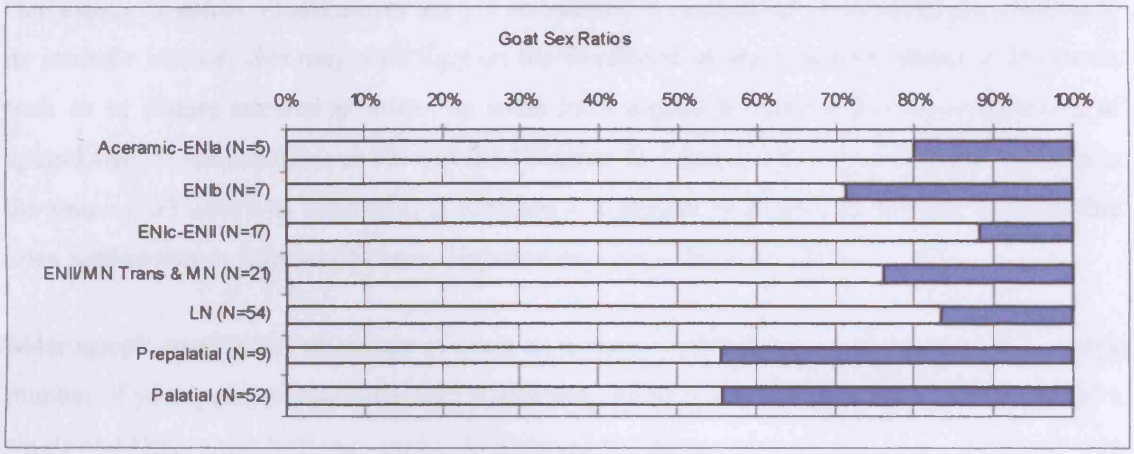


Figure 7:22 Frequencies of male and female goat pelves by sub-phase (MinAU; N=number of cases).

7.8.3 Conclusion

Although it is not entirely clear whether all remains belong to true domesticates, foetal/newborn remains suggest that at least some of the goats were bred in or near the settlement throughout prehistory. The size of the animals does not seem to be affected by human control, remaining stable in the periods under study. Two likely explanations can be put forward: first, that the environment and vegetation closely approximate the goat's natural habitat, securing high nutritional planes, and, secondly, that feral populations may have become established during prehistory, although it is not possible at present to reach a firm conclusion on the basis of measurements alone. During the Neolithic, a pattern of mixed purpose management is revealed by the analysis of dental ageing and sex ratios, while in the BA, already from the Prepalatial period, there appears to be a shift towards more specialised rearing of adult males for hair and/or large carcasses.

7.9 Seasonality of slaughter and habitation

One aspect of animal management not yet considered is seasonality of slaughter. In addition to its intrinsic interest, this may shed light on the likelihood of seasonal movements of livestock, such as to distant summer pastures, as some have argued in relation to the proliferation of upland sites at various times in FN and BA (Chapter 1). Likewise, it may confirm or leave open the year-round nature of habitation at Knossos – a subject of dispute in the case of Neolithic open settlements in mainland Greece (Halstead *in press a*; Whittle 1997).

Macroscopic assessment of season of death in domestic animals has two prerequisites: a large number of young (especially first-year) deaths that can be aged with reasonable accuracy; and a single and fairly short birthing season. At Knossos, the former prerequisite is met by sheep, pigs and, to a lesser extent, goats, but not by cattle. The latter prerequisite, under traditional extensive methods of husbandry (i.e. without intensive feeding), was largely met by sheep and goats, but less so by pigs because of their shorter gestation period. Accordingly, the analysis of seasonality of slaughter is restricted here to sheep and goats dying in their first year.

Two types of evidence are presented in

Table 7:11: foetal/neonatal specimens, taken to represent deaths within one month either way of the birth season; and mandibles, assigned to sub-divisions of Payne's age stages by Jones (*in press*) and attributed to absolute ages following Jones (*in press*), in the case of sheep, and Deniz and Payne (1982), in the case of goats. Both types of evidence are presented only in presence/absence terms, because quantification is likely to be misleading, given the acute biases of retrieval and survival afflicting such young remains and also the difficulty of assigning fragmentary young mandibles to the narrow age stages used here. Individual specimens may be incorrectly assigned to season, because of variation in birth date, timing of tooth eruption or speed of dental wear, but it is unlikely that the overall pattern observed is an artefact of such uncertainties.

The overall pattern is clear. Deaths take place throughout the first year and, within the limitations of small sample sizes and variable precision of taxonomic identification, this overall pattern seems to hold for both species and for all phases of the Neolithic and Bronze Age. Thus, throughout the six millennia under investigation here, Knossos was probably occupied year-round by at least some of its inhabitants and by some of their domestic animals. There is no evidence that flocks of sheep and goats from Knossos were taken to distant seasonal pastures, although it should be acknowledged that selective removal of, for example, adult sheep and goats would not be detectable in this analysis.

Table 7:11 Seasonality of slaughter of first year sheep and goats by sub-phase (M=molar; d4=deciduous premolar; E=erupting; U=unworn; W=in wear; x=sheep/goat; s=sheep; g=goat; age stages for sheep based on Jones (in press); age stages for goats based on Deniz and Payne (1982)).

	Age in months												
Age Stage	Sheep	Goat	Aceramic	ENIa	ENIb	ENIc-ENII	MN	LN	EM	MMIA	Protopalatial	Neopalatial	Final Palatial
Foetal/ Neonatal	<1	<1	X	X	X	X	X	X	X		X	X	
d4W M1U	1-2	1-3				S	G	S G					
M1E	3	2-5			S	S	S G	S G	S G			S G	G
M1WM2U (C1-2)	3-6	4-6	S		S	S G	S G	S G	S			S G	
M1W M2U (C3-4)	5-9	5-8			S G	S	S	S G	S				S
M1W M2U (C5)	6-10	6-11			S G	S G	S	S G	S			G	
M1W M2U (C6+)	8-11	7-11	S		S G	S G	SG	S G	S			S	S
M2E	9-13	9-14	S		S	S	S	S G	S		S	S	

7.10 Synthesis and conclusion

Metrical analysis suggests that the pigs represented at Knossos included small numbers of feral (presumably hunted) individuals, as well as domesticates. In the case of cattle, sheep and, less certainly, goats, it has been argued that single populations of domestic animals are represented. Of the domestic populations, decrease in size through time is clear for sheep, and probable for cattle; conversely, pigs and goats – as far as can be judged given their small samples in the earliest Neolithic levels – apparently exhibit more stable body size. This suggests that sheep and cattle may have been more restricted in their feeding and/or breeding activities than the other MDT.

Analysis of age and sex data indicates that mortality curves were steepest in pigs, followed by sheep, then goats and finally cattle. To a large extent, this matches the contrasting reproductive rates of the MDT, with sows potentially producing two large litters per year and cattle, at the other extreme, probably producing less than one calf per year. These differences in mortality also probably reflect the goals for which each species was managed. Other than manure, pigs only offer primary (carcass) products, whereas pathological evidence suggests use of cattle for traction and a few infant cattle remains might reflect some early slaughter to enhance the availability of milk for human consumption. Moreover, the slightly slower mortality of goats than of sheep, despite the rather higher reproductive rate of the former, suggests some differences in management goals for the two species. Through the Neolithic, pigs are fairly intensively managed for the production of mainly small- to medium-sized carcasses, while the staggered slaughter of juveniles, subadults and young adults, and selective retention of adult females, of the other three MDT are consistent with management for a mixture of primary and

secondary products. In the Bronze Age, increased proportions of adult, and especially adult male, deaths in cattle, sheep and goats suggest a marked shift in management strategy, consistent with more specialised emphasis on traction, wool and hair, but a similar shift in mortality patterns is also observed in pigs, at least in the Palatial period, and a decline is also noted in BA cattle in the frequency of pathologies suggestive of traction stress. The possibility must also be considered, therefore, that the BA change in management practice represents a shift to rearing of very large carcasses. This issue is discussed further in Chapter 8, where the evidence for consumption and management of animals are considered together.

A final issue for brief consideration here is the relative frequency of the four MDT in *livestock* at Knossos. Changing frequencies of the MDT, evaluated in the light of chronological variation in recovery and attrition biases, were discussed above (Chapter 6) in the context of evidence for the consumption of *deadstock*. Relative frequencies of deadstock and livestock are only the same if all taxa are subject to the same rate of mortality, whereas at Knossos there are marked differences both between the four MDT and between the Neolithic and Bronze Age. It is not possible to 'correct' the deadstock proportions of Table 6:16 into livestock proportions, because the mortality data for each of the MDT are too coarse, and anyway this would be potentially misleading given the varying vulnerability of each species to partial survival and retrieval. It is possible, however, to identify the major differences between deadstock and livestock proportions. In both the Neolithic and BA, deadstock proportions significantly underestimate the contribution to livestock of long-lived cattle and significantly overestimate that of short-lived pigs; for similar reasons, the contribution of sheep to livestock may be slightly overestimated relative to that of goats. Because of the observed shift in mortality patterns between the Neolithic and BA, the underestimation of cattle (and, to a lesser extent of sheep and goats) and the overestimation of pigs among livestock should be much more severe in the latter period. These adjustments do not affect arguments over increasing consumption of cattle during the Neolithic (above, 6.6), but are relevant to any attempt to relate livestock proportions to available pasture resources or to compare faunal evidence with the overwhelmingly livestock-related textual evidence.

8 CONCLUSIONS

8.1 Introduction

This final chapter has three aims: first, to summarise the conclusions drawn from the analysis of Knossian faunal assemblages, following the order of Chapters 5,6 and 7; secondly, to use the results from the present analysis in a diachronic synthesis for prehistoric Knossos; finally, to assess which of the questions raised in Chapter 1 have been answered more or less satisfactorily and to consider the potential of further study and different analytical methods to address those which remain unanswered.

8.2 Summary of analysis

Analysis of the effects of excavation and post-excavation history of the assemblage (Chapter 5) concluded that the assemblage was affected in the following ways. The most important destructive agents were transport, followed by poor storage. They reduced usable sample sizes for Evans1 due to breakage, which affected mostly the analysis of fragmentation patterns and reduced the number of measurable specimens. It can be concluded that long-distance transport is highly detrimental for faunal assemblages and that every effort should be made to analyse material in the proximity of an excavated site, and promptly, if possible. Analysis of recovery methods verified observations by previous researchers of the partial recovery of smaller body parts and smaller-bodied taxa and thus, presumably, younger individuals, although the effects were not as dramatic as those observed by Payne at Sitagroi (Payne 1973).

The presence of some burrowing taxa (badger, marten and rodents) suggests that some at least of the deposits had been disturbed post-depositionally but not overwhelmingly so. In terms of post-depositional agents, gnawing by scavengers was most important, substantially affecting, as expected, both anatomical representation and fragmentation patterns of the smaller-bodied taxa (i.e. pigs, sheep/goats). Moreover, fluctuations were observed – some fairly dramatic – between different sub-phases: the Neolithic – with the exception of the Aceramic – and EM assemblages were significantly more frequently gnawed than the Palatial. The results from the analysis of the two most severe biasing agents, partial recovery and gnawing, suggest caution in interpreting differences in taxonomic and elemental composition of the assemblage, as well as age profiles, between periods and areas. Particular care was thus taken in interpreting data from the ENIb-ENII and EM sub-assemblages most affected by gnawing, and from the sieved Evans2 Aceramic-ENII/MN Transition sub-assemblages.

Some conclusions could also be drawn from the study of scavenger attrition, however, in relation to human activity. Spatial differentiation in gnawing, observed in EN sub-assemblages, was tentatively attributed to the different character of the WC (refuse dump) and CC (mostly habitation area). This marked difference mostly disappears in MN and LN, when houses appear also in the WC. A similar pattern was observed in EM, where gnawing was less frequent in built-up areas, such as the WCH than in possibly open spaces excavated in RRN. Most importantly, the marked difference between high levels of gnawing in Neolithic and EM deposits, on the one hand, and low levels in Palatial deposits, on the other, is compatible with the highly formalised character in the latter period of the RR (which constitutes the bulk of the analysed material), an area within the public/elite core of the site. Significantly, the frequency of gnawing in the more remote HH, lying outside the 'special' area is comparable with that from EMIIA WCH, rather than the rest of the Palatial material. This suggests that the lower frequency of gnawing in Palatial material is more a spatial than a temporal phenomenon, and accentuates the special character of the RR deposits, summarised below.

Processing, consumption and discard of animals was clarified by the analysis of taxonomic composition, skeletal element representation, butchery marks and fragmentation patterns (Chapter 6). First, it is evident that all MDT in all periods were slaughtered and their carcasses processed in or around the excavated areas, as all parts of the skeleton are present in the vast majority of the deposits. It is possible, however, that in the Palatial period, *primary* processing – slaughter and dressing – of some cattle carcasses took place in other areas, given the under-representation of cattle skull specimens. There is no evidence, however, for large-scale processing of carcasses in spatially defined areas, such as the pits routinely encountered in Roman and medieval urban contexts in north-western Europe (e.g., Maltby 1985). The practice of the entire operational chain within the excavated area of the site is also evidenced by the observation of all types of butchery marks, including skinning, dismembering and filleting. In terms of the intensity of processing, cattle and mature animals were more thoroughly exploited, as long bones were systematically cracked open, presumably to extract marrow. Some temporal variability could also be observed. The Neolithic practice of skinning around the second phalanx of cattle suggests a greater concern for retrieving more of the skin than in the Palatial period, when skinning higher up the foot suggests emphasis on time-efficiency.

A similar concern with time-efficiency is not apparent, however, in the selection of tools for use in butchery. Important insights into technological innovation are provided by the wholesale adoption of *metal* cutting tools already in the EM period. This is reflected in the morphology of butchery marks on EMI and later faunal remains, as well as the abandonment of chipped stone and animal bones as raw materials for tool manufacture after the end of the Neolithic, although

bone – and possibly horn – were still used in the manufacture of prestige artefacts in the BA. Metal knives were joined by metal saws and possibly cleavers during the course of the EM, but the former seem only to have been used in bone- and horn-working and the latter were used rather rarely in butchery. Moreover, contrary to expectations based on time-efficiency, cleavers were not used more frequently in the butchery of cattle than of smaller pigs, sheep and goats.

Temporal differences are also observed in the intensity of butchery as reflected in the frequency and placement of butchery marks. The Neolithic and EM are characterised by the sectioning of carcasses of all MDT into large portions, a practice which is unaffected by the switch from stone to metal knives. In the Palatial period, meat joints are smaller and also more intensively filleted, while a distinctive type of butchery – multiple transverse parallel marks on long bones of pigs and sheep/goats – is also observed. Both the Neolithic-EM division of carcasses into large joints and the more intensive butchery – dismembering and filleting – of the Palatial period seem to be applied alike to cattle and the smaller pigs and sheep/goats and so are apparently dictated by neither the capacity of ovens or cooking pots nor by the size of the commensal group. The reduction in size of meat parcels, therefore, may reflect a change in the character of meat distribution or commensal events, in terms of participation and/or etiquette, between the Neolithic/EM and Palatial periods.

The existence of special commensal events in the public/elite core area during the Palatial period may be evidenced by the appearance of the exotic fallow deer in consumption debris and by the careful disposal of articulating groups of meat-bearing bones in structured deposits (e.g., LMIA Pit G[1]), together with cooking, serving and consumption vessels, arguably to mark such events. Significantly, no such deposits of Neolithic or EM date have been identified to-date and there is evidence that not all such deposits would have been destroyed post-depositionally, since manifestly undisturbed deposits (e.g., with articulating phalanges and/or metapodials, matching unfused epiphyses and diaphyses) occur in these periods. This suggests that the scattering of faunal remains from all MDT and all parts of the skeleton in Neolithic contexts may well reflect routine sharing and/or distribution of parts of the carcass within the community. Conversely, the indications of structured deposition in the Palatial period suggest large-scale consumption events of a more asymmetrical nature, with the hosts (presumably the palatial elite) providing hospitality to guests. In this context, the distinctive practice of transverse cutting may be designed to ensure equal distribution to guests.

[1] As yet, the size of the participating body cannot be ascertained, since it is not clear whether this particular feature has been preserved in its entirety or was truncated by later activity.

Finally, analysis of sex, age, metrical and pathological data provided insights into the status of the animals represented in the faunal assemblage and into the management of domesticates (Chapter 7). Average body-size through the Neolithic and BA remained more or less constant, in the case of pigs and goats, and declined only modestly, in the case of cattle. In each case this seems to be independent of changing ratios of male to female animals, suggesting high levels of nutrition and/or selection of large body size. The causes, which may have acted individually or in combination and may differ between periods, could be: a) 'free range' herding, viable in an insular context where predators are absent; b) deliberate breeding of large-bodied animals for symbolic and/or practical reasons (e.g., traction); c) existence of feral populations which were hunted and/or interbred with domestic stock. Of these, (a) is plausible for pigs, goats, and perhaps cattle, due to the suitability of the surrounding environment and expected natural vegetation around Knossos in prehistory; (c) is best supported by the metrical evidence for pigs, which suggests the existence of two distinct populations within the measured samples for some of the periods under study, and is possible for goats, although it cannot be proven using zooarchaeological data available to-date. Finally, (b) is likely for cattle: the ideological importance of cattle in Neolithic and BA Knossos is supported by iconographic evidence[2], while use of cattle in traction is hinted at by traction-related pathologies observed from ENIc onwards. Conversely, the clear decrease in average size of sheep through the Neolithic is consistent with restricted movement and absence of a feral population. The increase in sheep size in the BA is most economically interpreted as a result of the higher proportion of males and older animals, linked with a shift in management strategy.

Age and sex data for the Neolithic suggest a mixed strategy of management for cattle, sheep and goats throughout. The appearance of traction-related pathologies on female cattle pelves accentuates the lack of specialisation or intensification, implying usage of these animals for breeding, traction and, quite possibly, milking. The frequency of male cattle remains constant through the Neolithic arguing against intensification in management for traction. In a similar fashion, although artefacts interpreted as weaving equipment appear in the later Neolithic (end of ENII), leading to suggestions of the existence of woolly sheep, there is no evidence for the large-scale rearing of male sheep that are best suited for wool production.

Conversely, there is an obvious change in the BA, when older age profiles of cattle, sheep and goats and increased proportions of males are compatible with specialised husbandry practices. The management of cattle for traction and of sheep for wool are plausible interpretations, given the textual evidence for such exploitation in FP. Goats may similarly have been managed for

[2] Appearance of bull figurines in ENI; large range of cultic equipment and iconography depicting bulls: rhyta, frescoes, bull-leaping; sacrifice etc. (e.g., Vanschoonwinkel 1996).

hair, although FP textual evidence provides direct support rather for the collection of goat horns (Killen 1985). It must be recalled, however, that the Palatial sub-assemblage is almost entirely drawn from the elite/public core area of Knossos, where an emphasis on feasting has been suggested. The emphasis on large male cattle, sheep and goats in this period might, therefore, reflective selective consumption of the largest and most impressive animals, rather than specialised management for secondary products. This latter interpretation is perhaps supported by the high proportion of adult male *pigs* in the Palatial period, as pigs offer no secondary products. Likewise, it is consistent with indications that some Palatial feasting episodes were marked out by the consumption of exotic fallow deer or by selective consumption of particular domestic species (e.g., goats in LMIA Pit G). On the other hand, the EM assemblage also exhibits high proportions of adult and male cattle, sheep and goats, but otherwise, in terms of carcass processing and bone deposition, resembles the Neolithic rather than the Palatial assemblage. It is tempting, therefore, to link the change in mortality patterns between the Neolithic and EM periods with a shift towards management for secondary products rather than with the provisioning of feasts. In practice, however, this may be a false dichotomy in that the rearing of adult males for traction, wool or hair also yields large carcasses, and *vice versa.*

Differences between phases are also evident in the changing frequency of consumption of MDT. With due consideration for biases, it was concluded in Chapter 6, that whereas in the earlier Neolithic sheep are the most frequently consumed animals, with pigs, goats and cattle significantly less, from ENIc onwards, a fairly substantial increase in the consumption of cattle, pigs and goats was observed. The trend is briefly overturned in EM with a sharp increase in the consumption of sheep and a decrease of cattle and pigs, but a dramatic change in the taxonomic composition of the MMIA and Palatial assemblages culminates in a relatively balanced frequency of consumption of all four MDT in FP. It was explained also, that frequencies of the various taxa in deadstock do not equal relative proportions of animals alive at any given time, due to differences in breeding rates and ages which individuals of each taxon need to reach to make their slaughter worthwhile. Thus, comparing the four MDT, fewer pigs would have been necessary to replenish animals culled, more sheep and goats, and even greater numbers of the long-lived, slowly breeding and growing cattle. As mentioned before, such points are important when estimating livestock proportions to available pasture resources, or when comparing faunal evidence with the overwhelmingly livestock-related textual evidence.

8.3 Knossian bones in context

8.3.1 Neolithic

The absence of pre-Neolithic occupation on Crete and the sudden appearance, in the late 7th millennium BC, of a fully fledged Neolithic culture, complete with a 'Neolithic subsistence package', consisting certainly of cattle, pigs, sheep and goats, as well as, wheat and lentils provides sufficient evidence that the diffusion of the Neolithic was at least partly *demic* in origin, and that a 'Neolithic package' did exist and was, at least in some cases, transported *in toto* to new areas. The above points have already been made by other researchers (e.g., Broodbank and Strasser 1991; Halstead 1996a: 304), but such observations can be further qualified by results from the present analysis, and more recent evidence from Cyprus.

Cypriot sites dating to the 9th millennium BC – e.g., Parreklisha-*Shillourokambos* (e.g., Guillaine *et al.* 1996) and Kissonerga-*Mylouthkia* (e.g., Peltenburg *et al.* 2000) have been explored since the late 1990s, where the full 'Neolithic subsistence package' is attested (Peltenburg *et al.* 2000; Vigne *et al.* 1999). Comparison with the Knossian evidence suggests the following conclusions. First, Cyprus provides one of the earliest examples of demic diffusion and shows that cattle, pigs, sheep and goats were components of the animal 'package' from quite early on. Similarly, Knossos suggests the continuation of demic diffusion in later periods and of the persistence of the above components in the animal 'package'. Of course, the former observation does not negate the existence of parallel, indigenous adoption on the Greek mainland (e.g., Halstead 1996a; Kotsakis 2003) and elsewhere. Both Cyprus and Crete, however, constitute reliable contexts for the above conclusions, because of their insular character, and their location outside the natural geographic distribution of the wild progenitors of all the constituent elements of the animal package. In the case of these early Cypriot sites, the animals preserved for a long time the morphological characteristics of their wild progenitors, despite other evidence that they were closely herded (Vigne *et al.* 2000: 53). This in turn suggests that close herding may have passed unobserved on continental sites, because of the very slow rate of development in skeletons of managed animals of 'domestic' morphological traits, on the basis of which differentiation between 'wild' and 'domestic' forms in the areas of natural distribution of MDT has been routinely attempted (Peltenburg *et al.* 2000: 850; Vigne *et al.* 2000: 59).

A number of small mammals, like cats and foxes, well attested in early Cypriot sites – are also present at Knossos, although sporadically and not from the earliest levels. The date of their original introduction at Knossos remains uncertain for the time being: the small size of the earliest assemblages may mean that their absence is simply an effect of sampling. Similarly,

such few remains do not allow us to draw conclusions about the nature of the human-animal relationship, i.e. whether these animals had an economic and/or cultural role in early Neolithic societies, as sources of furs, as pets or as pest-controllers.

As regards the relative composition of assemblages, however, Knossos is distinctly different to at least one of these early Cypriot sites, Pareklisha-*Shillourokambos*, from which such data exist in published form. The major components of the fauna are pig, fallow deer and sheep/goat in a ratio of 4:2:1 (Peltenburg *et al.* 2000). At Knossos, *sheep* are the predominant species and fallow deer are represented by only a single specimen (more of which below). In this respect, Knossos resembles other early Neolithic sites on the Greek mainland (e.g., Halstead 1981a), where the predominance of sheep in early faunal assemblages has been interpreted as evidence for the existence of an 'integrated system of small-scale intensive crop husbandry regime' by Halstead (1992c): sheep were kept and partly grazed and simultaneously manured small plots in which crops were grown with intensive hoeing and weeding. If the Cypriot pattern is characteristic of very early sites, the Knossian pattern may reflect a system which developed later, involving closer integration of crop and animal husbandry regimes. Similar study of a greater number of sites of wider geographical distribution is necessary in order to test the validity of such hypotheses and the degree to which these represent temporal, rather than regional differences. Contrary to Crete, however, around the time of the establishment of Knossos, cattle become extinct on Cyprus, only to be re-introduced in EBA (e.g., Peltenburg *et al.* 2000)[3]. The continuing preponderance at Knossos of sheep and lack of evidence for changes in patterns of management in sheep, or any of the other MDT, suggests the persistence of this mode of husbandry until, at least, the end of ENIb.

The appearance of traction related pathologies on cattle in ENIc (early LN in mainland Greek terms), and increased numbers of cattle consumed in MN and LN at the expense of sheep, may signal significant change at Neolithic Knossos, as these phenomena observed in the faunal record are not isolated. Around this period Knossos could have reached a population size which made egalitarian structures non-viable, while animal figurines may imply a greater symbolic importance of cattle in relation to the other domesticates (Broodbank 1992; but see Whitelaw 1992). A possible scenario could be as follows. Population increase, suggested by the expansion of the settlement (J.D. Evans 1971; 1994), combined with decreasing fertility of cultivated land in the immediate vicinity of the site – inevitable at some stage after clearance of the Knossos valley and intensive land-use for about a millennium and a half – will have forced cultivation of larger areas and more remote fields, both in aggregate and by any individual productive unit. In

[3] It is not possible to discuss the importance of this difference in the context of the present study, but it is certainly an area which requires further exploration.

addition, probable expansion of cultivation outside the sheltered environment of the Knossos valley will have increased the likelihood of crop failure, which would have necessitated greater reliance on overproduction of grain, as the island offers few alternative wild food resources other than greens and snails. It is not impossible, depending on the ways in which land was distributed or 'inherited', that some social units may have become more successful due to their ability to cultivate better land. The need for cultivation of larger and more remote fields would have put a premium on animal-powered transport and ploughing. Due to the small samples from earlier ENI, it is not possible to say how early use of cattle in traction may have been. The increase in frequency of the animals and appearance of traction-related pathologies imply that such use became at least more common from ENII onwards.

Nevertheless, no signs of specialisation or intensification are observed in cattle husbandry, as age and sex structures in cattle apparently remain the same as those observed in Aceramic and ENIa/b (as do those of the other MDT), while some of the cattle used in traction in MN and LN are breeding females, which may also have been milked. Such multiple uses of cattle probably favoured large, robust animals, which could explain why the change in body-size of cattle is not dramatic during the Neolithic. Ownership of such animals would have signalled a successful household and may partly be the source of the loaded symbolism of cattle in later Minoan ideology. This importance of cattle would also have increased their value as animals consumed and may favour Broodbank's interpretation of the rising proportion of cattle consumed in MN-LN contexts as 'prestige food for conspicuous on-site butchery, consumption and discard' (Broodbank 1992: 62). The cultural significance of consuming the meat of such animals may have been further underlined by the use of elaborate presentation/consumption vessels since the end of ENII, a phenomenon also observed in mainland Greek sites (e.g., Pappa *et al. in press*). Their consumption, however, is not wasteful, as evidenced by the intensive processing of cattle bones for marrow extraction, which is a persistent characteristic of Neolithic cattle bones, while bones of all MDT, albeit with different frequency, are used fresh throughout the Neolithic for the manufacture of bone implements.

Despite the proposed changes in land-use and multiple uses of cattle between ENIb and the later Neolithic at Knossos, meat consumption does not seem to be affected. Meat parcels continue to be large and cattle used for traction are shared and consumed by the wider community in the same way as all other animals. At first sight, sharing of the carcasses by the wider community suggests that such social structures remained intact, but it is interesting that, around this period at Knossos, the 'household' becomes more evident as a distinct social and productive unit (Tomkins *in press*), as it has been argued by Halstead for the mainland Greek Neolithic (Halstead 1995c; 1999). The environmental parameters on Crete, with the increased risks of

crop failure and dearth of good arable land (mostly concentrated in coastal zones and thus affected by strong winter winds and problems of salinity) would have forced the 'household' to share carcasses following older traditions which may not have been as profitable as before, in view of the changed patterns of land- and animal use. The possibility remains, however, that not all households may have been able to contribute large animals, or at least not as frequently as others, which could gradually have created asymmetries and set apart particular households as more successful. Although excavations have exposed only limited parts of the settlement – and possibly only its centre – the existence in MN and LN of large 'houses' with multiple rooms imply that at least some large 'households' existed, even if, because of the above reason – we cannot ascertain presently how common or unusual they were. Finally, the unchanged age and sex structures of the deadstock imply that production is undertaken still at the 'household' level which does not allow or favour further intensification of production.

The absence of change in sex and age structures, as well as decrease of sheep in the later Neolithic, is at first sight incompatible with other archaeological evidence taken to imply wool production and weaving (i.e. the presence of possible weaving and spinning equipment from the late ENII onwards). Unless these artefacts have been mis-identified, their appearance from this period onwards may simply reflect the fact that the use of *non-perishable* materials, like clay, is the novelty and not their existence *per se*. Such a shift may also be meaningful, possibly denoting an increased importance of the associated activities.

The change in relative frequencies of MDT in MN and LN Knossos closely resembles the pattern observed in other LN Greek sites of a more balanced mixture of MDT (Halstead 1981a). This has been interpreted as the 'expansion of stock rearing beyond the arable sector by farmers colonising parts of the landscape more marginal for annual crops' (Halstead 1994: 202). As at Knossos, however, age and sex profiles do not hint at specialisation or intensification (Halstead 1987: 78, table 1 and fig. 3), although similar social and economic changes as at Knossos have been deduced from house architecture at Thessalian sites such as Dhimini, Sesklo and Aghia Sophia (Halstead 1994: 203).

Finally, at Knossos, the 'Secondary Products Revolution', or at least its traction component is possibly witnessed from ENIc, earlier than the 4^{th}-3^{rd} millennium BC date proposed by Sherratt (1981), and not as a 'package' with intensified milking and wool production, as is commonly envisaged[4]. The absence of evidence for intensification in milk production at Knossos insofar as

[4] A similar pattern has been observed in Neolithic Italy, where milking of goats, based on mortality patterns, has been identified at Arene Candide (Rowley-Conwy 2000).

mortality patterns are concerned, as well as at other Greek sites (Halstead 1989), makes this the least archaeologically supported component of the 'Secondary Products' package.

8.3.2 Bronze Age: Prepalatial[5]

The character of the transition between the latest Neolithic and the EBA at Knossos is obscure, not least because of the ongoing uncertainty about whether later activity destroyed the latest Neolithic occupation levels. Moreover, the limited number of undisturbed excavated EM deposits forces us to lump the results of the faunal analysis and thus possibly miss the exact timing of the changes observed, which are of great interest. They can be summarised as follows. A considerable change in the taxonomic composition of the EM assemblage is characterised by the preponderance of sheep and is accompanied by older age profiles for all MDT and increase in the numbers of male sheep, cattle and goats kept to adulthood. A renewed increase in sheep may be explained by the seasonal exploitation of areas well beyond the immediate catchment of the site (e.g., uplands), which may have been made possible by the availability of labour in the expanded Knossos of the Prepalatial period (with a population estimated at about 1300-1900 people – see Table 3.5). On the other hand, the sparse evidence for seasonality of lamb and kid deaths offers no support for seasonal use of distant pastures in EM. The increased proportions of adult and male cattle, sheep and goats, are the strongest evidence of a change in management involving intensification of secondary products, but could equally be due to the emphasis on rearing animals to achieve a larger body weight. An argument for the former interpretation is that the frequency of pigs, which can only produce meat, is reduced in this period. The latter interpretation is favoured by Wilson and Day's argument for the importance of feasting in EMI (although the faunal evidence from PW suggests that meat consumption did not play a role in such events). Choosing between the two might be a false dilemma, however, since one does not preclude the other. Nevertheless, innovative management strategies are not restricted to Knossos. Similar patterns are observed in faunal assemblages from other areas, while iconographic evidence suggest the importance for society of these changes. As mentioned above, cattle are re-introduced on Cyprus around this period. Age and sex composition of assemblages from Greek mainland sites shows changes comparable to those at Knossos: increased survivorship of male sheep and cattle reported from FN-MB Pefkakia (Jordan 1975) and EBA Dhimini suggests perhaps some intensification for wool and traction (Halstead 1994: 201). Knowledge and, evidently, importance of the plough is illustrated by artefacts such as the EB model of yoked plough oxen from Vounous (Cyprus), the EBII yoked oxen figurine from

[5] Unfortunately, for reasons already detailed in several instances, the size of assemblages, and the character of publications from other Cretan sites with Palatial period faunal remains provide very limited possibilities for comparison of animal management and consumption practices, and the reader should not be surprised by the lack of extensive comparisons with results from zooarchaeological studies from other Cretan sites.

Tsoungiza (Peloponnese) (Pullen 1992: 50, fig. 1), while the importance of keeping sheep flocks may be hinted by the EM bowl from Palaikastro, with densely packed miniature figures of sheep and a shepherd in its interior (Branigan 1988: plate 8b). It is more difficult to compare the Knossian faunal evidence with sites elsewhere in the island, due to the extremely small size of other assemblages, which in no case exceeds 200 identifiable specimens. All four MDT, however, are represented at Sentoni-Zoniana (Hamilakis 1998: 87, table 1; NISP=43), Myrtos-*Phournou Koryphi* (Jarman 1972; NISP=134) and Aghia Triadha (Wilkens 1996; NISP=195), while the presence of *only* sheep and goats at Debla (Warren and Tzedakis 1974; NISP=35) cannot be used as evidence for specialisation due to the small size of the assemblage. This suggests that mixed farming was practised by most communities, regardless of the ecological zone occupied by each of the above sites (Sentoni is located at about 600 masl, Aghia Triadha in the low hills overlooking the Messara plain, Myrtos on the dry southern coast).

The question to ask, perhaps, is how secondary produce like wool would have been turned into a commodity which could be exploited in some manner, e.g., exchanged. Other types of artefacts (pottery, figurines, jewellery, metal) circulated widely within Crete in this period, some imported from the Cyclades and the Greek mainland, suggesting that exchange networks and an emphasis on acquiring prestige artefacts is a widespread phenomenon in this period. Wool could be made into elaborate cloth, which is what happens in the Palatial period (see below) but this is impossible to identify archaeologically in a Cretan context. Either way such a use of wool cannot be proven and thus an economic importance of breeding wool sheep in a Prepalatial context cannot be ascertained.

Evidently, the available evidence is difficult to interpret and more contextual evidence is required. Interestingly, patterns of sectioning of animal carcasses are similar to those observed in the Neolithic, perhaps contrasting with changes in animal management. In view of the expansion of the settlement and the increase of population, however, the sharing of individual carcasses may have become progressively less socially inclusive through time.

In general this period is characterised by rather rapid change and innovation in various sectors compared to the Neolithic. One striking example is the rather swift abandonment of stone cutting tools in favour of metal knives (as evidenced by butchery marks)[6], although, as noted above, this does not affect the size of meat parcels. Similarly, bone is largely abandoned as a

[6] Evely's argument to the contrary, i.e. the continued use in the Prepalatial and Protopalatial of obsidian blades, alongside possibly daggers, which he considers to be part of 'everyday costume' (Evely 1993: 22), shows how problematic it is to draw conclusions about tool use solely on the basis of the number of archaeologically attested tools, from a highly recyclable and rather scarce raw material like metal.

raw material for the manufacture of implements[7], although it is used from this period onwards in the manufacture of prestige artefacts, possibly thanks to its resemblance to the exotic ivory, which is imported in small quantities from the east (Krzyszkowska 1983). Both these phenomena, therefore, suggest that great importance was attached to the use of metal implements, without, however, the emphasis being on their greater practical usefulness. This is an interesting observation concerning the adoption of innovations, which requires further exploration, beyond the scope of the present study. On the other hand, it has been convincingly shown – and can indeed be supported by the findings of the present study – that obsidian blades, the cutting tool *par excellence* of the Neolithic of southern Greece, become very special artefacts linked with body decoration and often specially made to be deposited in funerary contexts (Broodbank 2000: 250, fig. 79; Carter 1998).

8.3.3 The palaces

The most striking changes at Knossos are evident in Palatial contexts, and some may be discernible already in MMIA – with due consideration for the small size of the assemblage and its provenance mostly from a single deposit. The faunal assemblage from the Palatial period is dominated by material from LMI deposits, the small sizes of the Protopalatial and Final Palatial assemblages making separate analysis in most cases meaningless. This forces us to discuss the faunal evidence from all three Palatial sub-phases in combination, with the exception of MDT frequencies.

The first thing to observe is that in terms of the range of species bred there are no changes between the Palatial and earlier phases. The palaces appear to preserve established strategies of risk buffering, such as diversification in the range of species bred, but deadstock frequencies suggest a more even consumption of all MDT, with goats and pigs reaching their highest frequencies yet. The picture emerging from faunal remains is interesting in the light of textual evidence. Without the latter, one could have interpreted the faunal evidence as showing a mixed animal husbandry regime, with specialised management for secondary products suggested by the older age profiles of MDT and the increased frequency of males. Such a pattern was already observed in Prepalatial contexts, implying continuity in animal husbandry practices. Conversely, as already discussed in Chapter 3, Final Palatial Linear B texts provide evidence for the intensive breeding of thousands of wool sheep managed by the palace, while there is a distinct possibility that this was also the case in the preceding, Neopalatial period. Deadstock,

[7] Knossos provides sufficient evidence for this new trend, also hinted at by Evely (1993: 106-7), who refrained, however, from attaching great importance to this observation, since faunal assemblages had not been systematically studied at the time of the composition of his study. The present analysis and comparison of results from Kommos also covering most of the BA (Blitzer 1995) and Protopalatial Mallia (Poursat 1996) would tend to support the view that this is a true pattern, rather than one created by research bias.

however, as represented by the faunal remains discussed here, is silent on the massive scale of the operation and the preponderance of male sheep bred to an old age to produce wool among domesticates. The plough-oxen distributed by the palace, presumably large castrated males which could be recognised by the presence of pathologies, are equally absent. This is not surprising, in view of the fact that the vast majority of the faunal remains studied come from the public/elite core area of the site. Evidently, the palace elite is not interested in *consuming* these particular animals, but simply to acquiring the wool, keeping up flocks numbers and monitoring plough-oxen. Whether either are returned to the palace to be disbursed for consumption to more lowly palace dependents, or in feasts for the 'populace', is a question that requires the sampling of a wider range of areas, preferably outside the public/elite core, as well as other sites, administratively dependent on Knossos, in the 'non-palatial' sector (Halstead 2003: 258). This is not an impossible suggestion, however, since it is unlikely that the greatly increased population of Knossos (which could have reached up to 18000 inhabitants by the Neopalatial period) would have had access to sufficient land to breed animals for individual household consumption, and for display of generous hospitality by the palace. A similar scenario has been proposed by Halstead (1987: 83). No evidence in the faunal material studied was found for such massive scale events, which may arguably have taken place outside the public/elite core area, or even outside Knossos.

All evidence suggests that remains from the public/elite core of the site should be strictly regarded as representing very selective consumption of animals bred in a wider geographical area, and acquired for elite consumption, such as those animals apparently fattened or destined for slaughter attested in the Thebes sealings (Killen 1996). The high frequency of males can then be seen not as representative of regional management practices, with animals culled according to the demands for livestock secondary products, but as specialised selection of carcasses for particular occasions. Halstead notes the existence of tablet C (2) 914 which documents 'the dispatch of 50 rams and 50 male goats to a-ka-wi-ja, presumably the name or location of a festival of sufficient importance to warrant the slaughter of a hecatomb' (Halstead 1998-9: 160). Another characteristic of elite consumption of meat seems also to be careful preparation of carcasses and joints using fine tools[8], mainly knives and very infrequently heavy chopping tools, leading to sectioning into smaller parcels, a certain departure from the Neolithic and Prepalatial practices of butchery, underlining the restricted membership of such events. Such occasions, usually referred to as feasting ceremonies, and considered to be one of the mechanisms employed by the palatial elite for conspicuous display and creation of obligations

[8] Unless this pattern is an effect of sampling of a very unusual area, there is no evidence of large scale processing of carcasses for an urban market, using heavy tools, like cleavers and saws which are available from early on (Chapter 5) of the kind described in Roman contexts (e.g., Lignereux and Peters 1996).

to guests (Moody 1987b), possibly a device for collecting goods expected to be brought as gifts (e.g., Schmandt-Besserat 2001), may be reflected in the bone remains from the LMIA pit discussed at length in Chapter 6. The unusual frequency of goat remains in this context recalls Linear B tablets like C(4) 911 and 912 which list among others a flock of 180 male goats (Halstead 1998-9: 160). An alternative possibility is discussed below.

The palace, as well as running a bureaucratic system of monitoring production and collection of resources, was also involved in the manufacture of prestige items. Activities relevant to animal products, such as the production of elaborate wool textiles (e.g., Killen 1984) and preparation of skins, may not be visible in the faunal record, the latter other than in skinning marks on relevant body parts, but horn-working is probably evidenced by the sawn sections of horncores discussed in Chapter 6. Killen (2004: 385) discusses tablets Oa 1297 and On 300 on which the same person is mentioned as the donor, or recipient of commodities *189 (horn, five units) and *154 (skin, six units). It is interesting that the animal from which these are derived is not mentioned, but the faunal remains provide some evidence. Sawn horncores only of cattle and goats have been identified to-date, suggesting perhaps a greater suitability to working than sheep horns. Another interesting dimension provided by the faunal remains is the scale of these activities, which seems to match that suggested by the numbers listed in the above texts: such finds are rare, the largest concentration numbering just ten sawn tips of cattle horncores, underlining the specialised character of this industry. On the other hand, while faunal remains show that the involvement of the palace with such activities dates already to the Protopalatial period (Chapter 6), they do not provide evidence for the types of artefacts produced. Their luxury nature is evidenced in tablet Ra(2) from Knossos mentioning objects bound with horn and *ivory*, while Un 1482 from Pylos lists a number of objects to which horn was 'almost certainly attached': beds, footstools, saddle bags (Killen 2004: 387). Faunal remains provide another insight into the spatial organisation of artisanal activities. The identification of horn- and bone working remains within the elite/core area would support Killen's argument for close control, by the palace, of these activities. Perhaps the absence of a whole sequence of processing by-products, may also fit his ideas of the palace deliberately 'fragmenting' the process of manufacture, in order to stop individuals, or households from being able to produce complete such items, without palatial intervention (Killen 1985). As Halstead notes such strategies enabled the palace to control completely the production of 'valuable tokens', one of the buffering mechanisms which were probably used until the Prepalatial period by all parts of the society (Halstead 1994: 210-1).

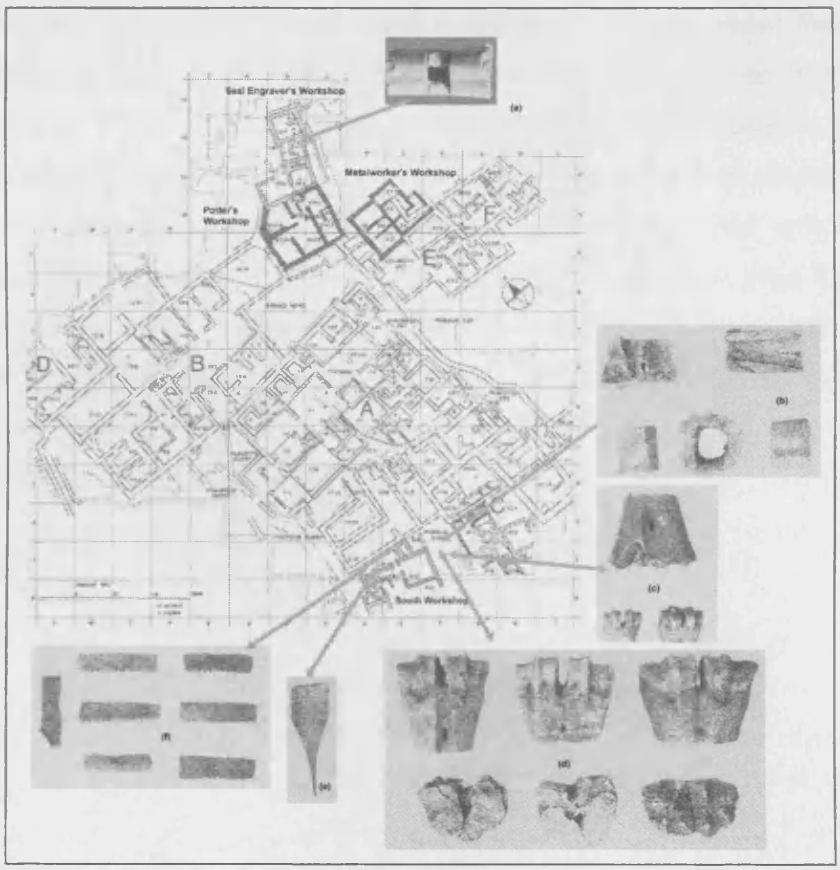


Figure 8:1 Bone working at Propopalatial Mallia
Plan of Quartier Mu, Palace of Mallia, showing workshops and find locations of tools and bone debris connected with manufacturing activities (compiled from Poursat 1996, plates 42,44,45 and 81).

A better understanding of the spatial organisation of *bone*-working is provided by the findings at Protopalatial Mallia, in Quartier Mu, where bone-working debris, blanks and tools were found in proximity to each other (Poursat 1996: 121) (Figure 8:1). The use of cattle bones in craft-working and the lack of any evidence from faunal remains for special treatment of cattle could be considered peculiar in view of the great symbolic importance of cattle, as implied by Minoan iconography. As pointed out by various researchers, cattle are the species most frequently represented by figurines deposited in peak sanctuaries (e.g., Peatfield 1992; Zeimbeki *in press*) and predominant in other iconographic media but their remains are not treated with special care.

8.3.4 Rarities: the case of deer and equids

So far discussion has not touched on the significance of the extreme rarity of deer and equids from the faunal record at Knossos, an important aspect of the faunal evidence. Starting with deer, a characteristic of early Neolithic Cypriot faunas, discussed above, is the fairly common occurrence of fallow deer, also introduced. A single specimen of a fallow deer – from a meaty

part of the skeleton, tentatively suggesting the presence of an animal, rather than a skin – in Knossian Aceramic levels, suggests that this species may have also been part of the package on Crete. Vigne *et al.* (1999: 53), on the basis of skeletal element representation, age and sex profiles, argue that fallow deer may have been introduced to Cyprus to be released in the wild and hunted, implying a symbolic importance attached to hunting in these early societies. At Knossos, the single specimen implies extreme rarity and the absence from later Neolithic contexts – with the exception of another single specimen from LN – perhaps indicates an unsuccessful introduction. Deer occur sporadically in Neolithic deposits, and are completely absent from Prepalatial ones, but are better represented in Neopalatial and Final Palatial contexts. Two species were identified at Knossos, red and fallow. The body parts and MinAU of only the latter provide good grounds for suggesting the existence of live animals on the island, either wild or penned, and then again only in the Neopalatial and Final Palatial periods. Red deer remains were represented in Neolithic deposits by single specimens. These are most economically interpreted as portions of dressed carcasses imported to the island, or single animals which never established breeding populations, as has already been suggested for the two specimens of fallow deer (from Aceramic and LN contexts). Analyses from other sites provide similar results: red deer have been reported from Neopalatial Aghia Triadha, Prinias (Wilkens 1996) and post-palatial Thronos-Amari and Chamalevri (Mylona 1999: 62-8), and fallow deer from post-palatial Thronos-Amari, Chamalevri (Mylona 1999: 63-8) and Kavousi-Kastro (Klippel and Snyder 1991) and Neopalatial Chania (Mylona 1999: 106), Kommos (Reese 1995b) and Aghia Triadha (Wilkens 1996). In all cases the animals are represented by very few specimens, occasionally extremities (it is not possible to assess these assemblages at present because of limited information provided in the, largely, preliminary reports from which the data derive). The pattern observed at Knossos thus probably holds true for the entire island.

While the rarity of red deer is not surprising, since, in Greek mainland assemblages these animals derive from wild hunted populations, non-existent on Crete, the absence in Neolithic and EM contexts of fallow deer is striking, in view of a fairly widespread introduction of the species on other islands, such as Saliagos, Rhodes and Thasos, and possibly even the mainland, in LN/FN and EBA[9] (Halstead 1987: 75, with exhaustive bibliography). Previous development of endemic forms of deer in the Pleistocene excludes the possibility that Crete does not offer a suitable ecosystem for the establishment of deer populations. Thus, we cannot resort to environmental explanations. Two possible scenarios can be proposed. First, if we accept that fallow deer in other areas were not closely herded but released in the wild and hunted – as the

[9] The arguments, especially chronological distribution of fallow deer finds presented by Becker (1997) for the survival of wild populations of fallow deer in Greece and the Balkans through the Last Glacial Maximum are not very convincing (all examples of Neolithic remains belong to late Neolithic sites), so here the view of Halstead (1987: 75) is adopted that fallow deer in the Greek mainland were introduced from further east.

evidence from Kalythies, Rhodes suggests (Halstead 1987: 75) – such a strategy may not have been viable on Crete if feral populations of other species had already been established, with which the newly introduced fallow deer would have had to compete for a niche. If the chronological horizon of the introduction of fallow deer is the LN-EBA, metrical evidence from Knossos has suggested that the existence of, at least, feral pigs is a distinct possibility. It is also possible that Cretans were not interested in introducing other species to the island, if other feral populations already existed. The body parts by which fallow deer are represented in Palatial deposits, however, suggest a different strategy. Both mandibles and feet of fallow deer are present in the, albeit small, assemblage, suggesting that these animals may have been penned, rather than released in the wild. Although fallow deer are not behaviourally well suited to the type of husbandry possible with MDT (Garrard 1984), a type of controlled breeding like that of Roman and later times in enclosures could have been practised on large estates of the Palatial period. This could explain why there is only one type of deer recorded in Linear B archives at Pylos, although two more species, red and roe deer, presumably existing in the wild, were also consumed. Arguably, textual monitoring only made sense for known populations of animals (therefore managed in some sense), rather than individuals procured in the wild.

This late introduction and possibly close monitoring in the Palatial period, which departs from the evidence from other areas of Greece and Cyprus, lends support to the elite character of the consumption and ownership of fallow deer by the palace.

Finally, the extreme rarity of equid remains in the present assemblage from Knossos is striking. It lends support, however, to the observations of other researchers, especially in relation to textual evidence, where these animals were referred to only in connection with chariots and never in consumption texts, that they were rarely, if at all consumed and used mainly for transport, display, hunting, etc. (e.g., Halstead 1998-9: 186).

8.4 What next?

In the first chapter of this study a number of research questions were highlighted for which faunal analysis has the potential to provide answers. These were as follows:

1. Agricultural colonisation and anthropogenic impact on the Cretan mammalian fauna;
2. The role of practical and symbolic consumption of animals in social change at Knossos during the course of the Neolithic;
3. The role of secondary products exploitation and pastoralism in changing settlement patterns at the end of the Neolithic and of the Bronze Age and in the location of peak sanctuaries;

4. The role of animal management and consumption in the development and financing of Minoan palatial society;
5. The role of animals in religion and ritual as reflected in iconographic representations.

Chapter 2 argued that, in agreement with previous researchers, Knossos was settled by early Neolithic farmers with an 'animal subsistence package', but there is no evidence that these introduced animals, or indeed any of the activities undertaken by Neolithic Knossians led to the extinction of the endemic fauna, which appears to have disappeared, for as yet unknown reasons, from the island before the arrival of the colonists.

Faunal evidence was also able to provide useful insights into the nature of animal management and consumption during the Neolithic. Communal sharing of meat is implied by the large size of Neolithic meat packages and the emphasis on producing large carcasses – as shown by the age profiles of MDT. Thus, meat consumption could have been one of the mechanisms of maintaining cohesion in a situation where conflict between individual 'households' and the wider community was probably intensifying through time, as land resources became scarcer and the disincentive to share one's own produce greater.

Evidence for management did not support the existence of a 'Secondary Products Revolution', at least insofar as there was no evidence for all its components (i.e. traction and intensification of milk and wool production) being adopted at once, supporting previous arguments that such strategies are adopted and would be visible in archaeological contexts only in certain socio-economic contexts.

The limited, admittedly, evidence for seasonality did not provide any hints for seasonal movements of animals from Knossos to more remote areas, thus not lending any support to arguments about the advent of transhumance in the FN/EM period on Crete.

Palatial faunal remains suggested a selective consumption of animals by the palatial elite, which does not reflect decisions dictated by the specialised animal husbandry strategies manifested in the Linear B texts, implying that bones discarded in the public/elite core area of Knossos strictly represent consumption and not management practices. Evidence was also provided for the possibility of feasting within this central area, where meat consumption probably played an important role, enhanced by cuisine and consumption of rare animals, like fallow deer. Craft-working debris also showed how the palace used by-products of meat consumption in its specialised craft industry.

No evidence was provided for special treatment of the remains of animals most prominent in Minoan symbolism, cattle and 'agrimia', while for the latter it was not possible to state firmly whether feral populations existed. The possibility that feral pigs, however, were extant was put forward, which lends some support to arguments for hunting.

Evidently, while some questions have been answered in a relatively satisfactory manner, this is not the case for all. The existence of feral animals and, indeed, the movement of domestic animals may be better explored by isotopic analysis and dental microwear studies (cf. similar studies by Richards et al. 2003) to identify different sources of feeding. Even with existing macroscopic methods, more excavations at Knossos, in areas outside the elite core, would provide insights into spatial organisation of consumption and the degree to which the characteristics of meat consumption observed in the elite core are representative of different – non-elite – sectors of the site. Similarly, studies of material from lower ranking Palatial sites would enhance our understanding of animal management and consumption by the rest of Minoan society.

Perhaps most important of all – given that faunal remains from at least some types of context are a finite resource – is the need for future studies to be based on faunal remains that have been carefully excavated, systematically recorded, and fully contextualised.

BIBLIOGRAPHY

Agouridis, C. (1997). 'Sea routes and navigation in the third millennium Aegean'. *Oxford Journal of Archaeology* **16**: 1-24.

Alhaique, F. (1997). 'Do patterns of bone breakage differ between cooked and uncooked bones? An experimental approach'. *Anthropozoologica* **25-26**: 49-56.

van Andel, T., and C. Runnels (1988). 'An essay on the "emergence of civilization" in the Aegean world'. *Antiquity* **62**: 234-47.

van Andel, T., and J.C. Shackleton (1982). 'Late Palaeolithic and Mesolithic coastlines of Greece and the Aegean'. *Journal of Field Archaeology* **9**: 445-54.

Armitage, P.L., and J. Clutton-Brock (1976). 'A system for classification and description of the horncores of cattle from archaeological sites'. *Journal of Archaeological Science* **3**: 329-48.

Atherden, M. (2000). 'Human impact on the vegetation of southern Greece', in: P. Halstead (ed.), *Landscape and Land Use in Postglacial Greece*: pp. 62-78. Sheffield: Sheffield Academic Press.

Baker, J., and D. Brothwell (1980). *Animal Diseases in Archaeology*. New York: Academic Press.

Barrett, J., and P. Halstead (eds) (2004). *The Emergence of Civilisation Revisited*. Oxford: Oxbow.

Bartosiewicz, L., W.van Neer, and M. Fabis (1997). *Draught Cattle: their Osteological Identification and History*. Tervuren: Musée Royal de l'Afrique centrale.

Bate, D.M.A. (1905). 'On the mammals of Crete'. *Proceedings of the Zoological Society of London* **II**: 315-23.

Becker, C. (1997). 'Zur nacheiszeitlichen Verbreitung des Damhirsches *Cervus dama* in Südeuropa - eine kritische Zwischenbilanz', *Xronos: Beiträge zur Prähistorischen Archäologie zwischen Nord- und Südeuropa. Festschrift für Bernhard Hänsel*: pp. 67-82: Marie Leidorf.

Bedwin, O. (1984). 'Appendix 2: The animal bones', in: M.R. Popham (ed.), *The Unexplored Mansion at Knossos*: pp. 307-08.

Benecke, N. (1998). 'Animal remains from the Neolithic and Bronze Age settlements at Kirklareli (Turkish Thrace)', in: H. Buitenhuis, L. Bartosiewicz and A.M. Choyke (eds), *Archaeozoology of the Near East III*: pp. 172-79. Groningen: ARC.

Bennet, J. (1988). 'Approaches to the problem of combining Linear B textual data and archaeological data in the late bronze age Aegean', in: E.B. French and K.A. Wardle (eds), *Problems in Greek Prehistory*: pp. 509-18. Bristol: Bristol Classical Press.

— (2002). 'Millennial ambiquities', in: Y. Hamilakis (ed.), *Labyrinth Revisited: Rethinking "Minoan" Archaeology*: pp. 214-26. Oxford: Oxbow.

Bennet, J., and J. Davis (1999). 'Making Mycenaeans: warfare, territorial expansion, and representations of the other in the Pylian kingdom', in: R. Laffineur (ed.), *Polemos: le Contexte Guerrier en Égée à l'Âge du Bronze*: pp. 105-20. Liège: University of Liège.

Bez, J.-F. (1995). 'Une expérience de découpe bouchère pratiquée au silex: aspects anatomiques'. *Préhistoire et Anthropologie Méditerranéennes* **4**: 41-50.

Binford, L.R. (1978). *Nunamiut Ethnoarchaeology*. New York: Academic Press.

— (1981). *Bones: Ancient Men and Modern Myths*. New York: Academic Press.

Blitzer, H. (1995). 'Chapter 6: The utilitarian bone industry', in: J.W. Shaw and M.C. Shaw (eds), *Kommos I: The Kommos Region and Houses of the Minoan Town*: pp. 497-501. Princeton, New Jersey: Princeton University Press.

Boardman, J. (1963). *On the Knossos Tablets: the Date of the Knossos Tablets*. Oxford.

Boardman, S. (1994). 'Foreword', in: D. Evely, H. Hughes-Brock and N. Momigliano (eds), *Knossos: a Labyrinth of History, Papers presented in Honour of Sinclair Hood*: pp. xv-i. London: British School at Athens.

Boessneck, J. (1969). 'Osteological differences between sheep (Ovis aries Linné) and goats (Capra hircus Linné)', in: D. Brothwell and E. Higgs (eds), *Science in Archaeology*: pp. 331-58. London: Thames and Hudson.

Boessneck, J., H.H. Müller, and T.M. Teichert (1964). 'Osteologische Unterscheidungsmerkmale zwischen Schaf (*Ovis aries* Linné) und Ziege (*Capra hircus* Linné)'. *Kuhn Archiv* **78**: 1-29.

Bökönyi, S. (1986). 'Animal remains', in: C. Renfrew, M. Gimbutas and E.S. Elster (eds), *Excavations at Sitagroi: A Prehistoric Village in Northeast Greece, I*: pp. 63-132. Los Angeles: UCLA, Institute of Archaeology.

— (1989). 'Animal remains', in: M. Gimbutas, S. Winn and D. Shimabuku (eds), *Achilleion: a Neolithic Settlement in Thessaly, Greece, 6400-5600 BC*: University of California.

Borgna, E. (1997). 'Kitchen-ware from LM IIIC Phaistos: cooking traditions and ritual activities in LBA Cretan societies'. *Studi Micenei ed Egeo-Anatolici* **39**: 189-217.

Bottema, H. and Sarpaki, A. (2003). 'Environmental change in Crete: a 9000-year record of Holocene vegetation and the effect of the Santorini eruption'. *The Holocene* **13 (5)**: 733-49.

Brain, C.K. (1981). *The Hunters or the Hunted?* Chicago: Chicago University Press.

Branigan, K. (1974). *Aegean Metalwork of the Early and Middle Bronze Age*. Oxford: Clarendon Press.

— (1988). *Prepalatial: the Foundations of Palatial Crete.* Amsterdam: Adolph Hakert.

Broodbank, C. (1992). 'The Neolithic labyrinth: social change at Knossos before the Bronze Age'. *Journal of Mediterranean Archaeology* **5**: 39-75.

— (1999). 'Colonisation and configuration in the insular Neolithic of the Aegean', in: P. Halstead (ed.), *Neolithic Society in Greece*: pp. 15-41. Sheffield: Sheffield Academic Press.

— (2000). *An Island Archaeology of the Early Cyclades*. Cambridge: Cambridge University Press.

Broodbank, C., and T.F. Strasser (1991). 'Migrant farmers and the Neolithic colonisation of Crete'. *Antiquity* **65**: 233-45.

Bull, G., and S. Payne (1982). 'Tooth eruption and epiphysial fusion in pigs and wild boar', in: B. Wilson, C. Grigson and S. Payne (eds), *Ageing and Sexing Animal Bones from Archaeological Sites*: pp. 55-71. Oxford.

Burke, A. (2000). 'Butchery of a sheep in rural Tunisia (North Africa): repercussions for the archaeological study of bone disposal'. *Anthropozoologica* **32**: 3-10.

Cadogan, G. (1987). 'What happened at the Old Palace of Knossos?' in: R. Hägg and N. Marinatos (eds), *The Function of the Minoan Palaces*: pp. 71-74. Stockholm: Swedish Institute at Athens.

Cadogan, G., P.M. Day, C.F. Macdonald, J.A. MacGillivray, N. Momigliano, T. Whitelaw, and D.E. Wilson (1993). 'Early Minoan and Middle Minoan pottery groups at Knossos'. *Annual of the British School at Athens* **88**: 21-28.

Callou, C. (1997). *Diagnose différentielle des principaux éléments squelettiques du lapin (genre Oryctolagus) et du lièvre (genre Lepus) en Europe Occidentale*. Valbonne-Sophia Antipolis: Centre de Recherches Archéologiques du CNRS (Fiches d' Ostéologie animale pour l'Archéologie. Série B: Mammifères, 8).

Carter, T. (1998). 'Reverbations of the international spirit: thoughts upon 'Cycladica' in the Mesara', in: K. Branigan (ed.), *Cemetery and Society in the Aegean Bronze Age*: pp. 59-77. Sheffield: Sheffield Academic Press.

Chadwick, J. (1958). *The Decipherment of Linear B*. Cambridge: Cambridge University Press.

Chaniotis, A. (ed.) (1999). *From Minoan Farmers to Roman Traders: Sidelights on the Economy of Ancient Crete*. Stuttgart: Franz Steiner Verlag.

Cherry, J.F. (1981). 'Pattern and process in the earliest colonisation of the Mediterranean islands'. *Proceedings of the Prehistoric Society* **47**: 41-68.

— (1983). 'Evolution, revolution and the origins of complex society in Minoan Crete', in: O. Krzyszkowska and L. Nixon (eds), *Minoan Society*: pp. 33-45. Bristol: Bristol Classical Press.

— (1984). 'The emergence of state in the prehistoric Aegean'. *Proceedings of the Cambridge Philological Society* **210**: 18-48.

— (1986). 'Polities and palaces: some problems in Minoan state formation', in: A.C. Renfrew and J.F. Cherry (eds), *Peer Polity Interaction and Socio-Political Change*: pp. 19-45. Cambridge: Cambridge University Press.

— (1988). 'Pastoralism and the role of animals in the pre- and proto-historic economies of the Aegean', in: C.R. Whittaker (ed.), *Pastoral Economies in Classical Antiquity*: pp. 6-34. Cambridge: Cambridge Philological Society.

— (1990). 'The first colonisation of the Mediterranean islands: a review of recent research'. *Journal of Mediterranean Archaeology* **3**: 145-221.

Childe, V.G. (1957). *The Dawn of European Civilization*. London: Routledge.

Clarke, D.L. (1973). 'Archaeology: the loss of innocence'. *Antiquity* **47**: 6-18.

Collins, P. (1987). *Getting into the Groove: an Experiment to find Differences between Cut-marks made by Non-metal and Metal Tools*. [Unpubl. BA dissertation, University of Sheffield].

Collins, P., and P. Halstead (1999). 'Faunal remains and animal exploitation at LN Makrigialos: preliminary results', in: P. Halstead (ed.), *Neolithic Society in Greece*: pp. 139-41. Sheffield: Sheffield Academic Press.

Croft, P. (1991). 'Man and beast in Chalcolithic Cyprus'. *Bulletin of the American School of Orientalist Research* **282-3**: 63-79.

Cucchi, T., J.-D. Vigne, J.-C. Auffray, P. Croft, and E.J. Peltenburg (2002). 'Introduction involontaire de la souris domestique (*Mus musculus domesticus*) à Chypre des le Néolithique précéramique ancien (fin IX^{e} et VIII^{e} millénaires av. J.-C.)', in: C.R. Palevol (ed.), *Paléontologie Humaine et Préhistoire*: pp. 1-7.

de Cupère, A., A. Lentacker, W.van Neer, M. Waelkens, and L. Verslype (2000). 'Osteological evidence for the draught exploitation of cattle: first applications of a new methodology'. *International Journal of Osteoarchaeology* **10**: 254-67.

Dahl, G., and A. Hjort (1976). *Having Herds: Pastoral Herd Growth and Household Economy*. Stockholm: University of Stockholm (Stockholm Studies in Social Anthropology 2.

Davis, S.J. (1987). *The Archaeology of Animals*. London: Batsford.

Day, P., D.E. Wilson, and E. Kiriatzi (1998). 'Pots, labels and people: burying ethinicy in the cemetery at Aghia Photia, Siteias', in: K. Branigan (ed.), *Cemetery and Society in the Aegean Bronze Age*: pp. 133-49. Sheffield: Sheffield Academic Press.

Deniz, E., and S. Payne (1982). 'Eruption and wear in the mandibular dentition as a guide to ageing Turkish Angora goats', in: B. Wilson, C. Grigson and S. Payne (eds), *Ageing and Sexing Animal Bones from Archaeological Sites* (BAR British Series: 109): pp. 155-205. Oxford: British Archaeological Reports.

Diamond, J.M. (1984). 'Historic extinction: a Rosetta stone for understanding prehistoric extinctions', in: P.S. Martin and R.G. Klein (eds), *Quaternary Extinctions: a Prehistoric Revolution*: pp. 824-66. Tucson: University of Arizona Press.

— (1989). 'Quaternary megafaunal extinctions: variations on a theme by Paganini'. *Journal of Archaeological Science* **16**: 167-75.

Dickinson, O.T.P.K. (1994). *The Aegean Bronze Age*. Cambridge: Cambridge University Press.

Dimopoulou, N. (1997). 'Workshops and craftsmen in the harbour-town of Knossos at Poros-Katsambas', in: R. Laffineur and P.P. Betancourt (eds), *Techne: Craftsmen, Craftswomen and Craftsmanship in the Aegean Bronze Age*: pp. 433-38. Liège: University of Liège.

Dottrens, E. (1946). 'Étude préliminaire: les phalanges osseuses de *Bos taurus domesticus*', in: P. Revilliod and E. Dottrens (eds), *La Faune Néolithique de la Couche Profonde de Saint Aubin. Revue Suisse de Zoologie*.

von den Driesch, A. (1976). *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Cambridge, MA: Peabody Museum of Archeology and Anthropology, Harvard University.

— (1987). 'Haus- und Jagdtiere im vorgeschichtlichen Thessalien'. *Prähistorische Zeitschrift* **62**: 1-21.

von den Driesch, A., and J. Boessneck (1990). 'Die Tierreste von der mykenischen Burg Tiryns bei Nafplion/Peloponnes', in: H.-J. Weisshaar, I. Weber-Hiden, A. von den Driesch, J. Boessneck, A. Rieger and W. Böser (eds), *Tiryns Forschungen und Berichte 11*: pp. 87-164. Mainz am Rhein: von Zabern.

von den Driesch, A., and K. Enderle (1976). 'Die Tierreste aus der Agia Sofia-Magoula in Thessalien', in: V. Milojcic, A. von den Driesch, K. Enderle, J. Milojcic-V. Zumbusch and K. Kilian (eds), *Die Deutschen Ausgrabungen auf Magulen um Larisa in Thessalien 1966*: Rudolf Habelt.

Driessen, J. (1990). *An Early Destruction in the Mycenaean Palace of Minos*. Leuven: Katholiek Universiteit Leuven.

— (2001). 'History and hierarchy. Preliminary observations on the settlement pattern in Minoan Crete', in: K. Branigan (ed.), *Urbanism in the Aegean Bronze Age*: pp. 51-71. Sheffield: Sheffield Academic Press.

Evans, A. (1894). 'Primitive pictographs and a prae-Phoenician script from Crete and the Peloponnese'. *Journal of Hellenic Studies* **14**: 270-372.

— (1906). *Essai de Classification des Époques de la Civilisation Minoenne*. London.

— (1921). *The Palace of Minos I.* London: MacMillan.

— (1928). *The Palace of Minos II.* London: MacMillan.

— (1935). *The Palace of Minos IV*. London: MacMillan.

Evans, J. (1943). *Time and Chance: the Story of A. Evans and his Forebears*. London: Longmans.

Evans, J.D. (1964). 'Excavations in the neolithic settlement of Knossos, 1957-60. Part I'. *Annual of the British School at Athens* **59**: 132-240.

— (1968). 'Knossos Neolithic, part II: summary and conclusions'. *Annual of the British School at Athens* **63**: 267-76.

— (1971). 'Neolithic Knossos: the growth of a settlement'. *Proceedings of the Prehistoric Society* **37**: 95-117.

— (1973). 'Sherd weights and sherd counts - a contribution to the problem of quantifying pottery studies', in: D.E. Strong (ed.), *Archaeological Theory and Practice (Festschrift in Honour of Prof. W.F. Grimes)*: pp. 131-49. London: Seminar Press.

— (1994). 'The early millennia: continuity and change in a farming settlement', in: D. Evely, H. Hughes-Brock and N. Momigliano (eds), *Knossos: a Labyrinth of History, Papers presented in Honour of Sinclair Hood*: pp. 1-22. London: British School at Athens.

Evely, D. (1993). *Minoan Crafts: Tools and Techniques*. Göteborg: Paul Åströms Förlag.

Ewbank, J., D. Phillipson, R. Whitehouse, and E. Higgs (1964). 'Sheep in the Iron Age: a method of study'. *Proceedings of the Prehistoric Society* **30**: 423-26.

Fassoulas, C.G. (2000). *Field Guide to the Geology of Crete*. Herakleio: Natural History Museum of Crete, University of Crete.

Forde, C.D. (1934). *Habitat, Economy and Society: a Geographical Introduction to Ethnology*. London: Methuen.

Garrard, A. (1984). 'The selection of southwest Asian animal domesticates', in: J. Clutton-Brock and C. Grigson (eds), *Animals and Archaeology 3* (BAR International Series: 202): pp. 117-32. Oxford: British Archaeological Reports.

Gejvall, N.-G. (1969). *Lerna, a Preclassical Site in the Argolid: Volume I: The Fauna*. Princeton, New Jersey: American School of Classical Studies at Athens.

Grant, A. (1982). 'The use of tooth wear as a guide to the age of domestic ungulates', in: B. Wilson, C. Grigson and S. Payne (eds), *Ageing and Sexing Animal Bones from Archaeological Sites* (BAR British Series 109): pp. 91-108. Oxford: British Archaeological Reports.

Greenfield, H.J. (1988). 'Bone consumption by pigs in a contemporary Serbian village: implication for the interpretation of prehistoric faunal assemblages'. *Journal of Field Archaeology* **15**: 473-79.

— (1999). 'The origins of metallurgy: distinguishing stone from metal cut-marks on bones from archaeological sites'. *Journal of Archaeological Science* **26**: 797-808.

Grigson, C. (1982). 'Sex and age determination of some bones and teeth of domestic cattle: a review of the literature', in: B. Wilson, C. Grigson and S. Payne (eds), *Ageing and Sexing Animal Bones from Archaeological Sites* (BAR British Series 109): pp. 7-23. Oxford: British Archaeological Reports.

Guerrero Ayuso, V.M. (2001). 'The Balearic islands: prehistoric colonisation of the furthest Mediterranean islands from the mainland'. *Journal of Mediterranean Archaeology* **14 (2)**: 136-58.

Guest-Papamanoli, A. (1996). 'Hunting and trapping in prehistoric Crete: a proposal for ethnoarchaeological research', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 337-49. Madison: Prehistory Press.

Guilaine, J., F. Briois, J. Coularou, J.-D. Vigne, and I. Carrere (1996). 'Shillourokambos et les debuts du Neolithique en Chypre'. *Espacio, Tiempo y Forma, ser. 1, Prehistoria y Arqueologia* **9**: 159-71.

Halstead, P. (1981a). 'Counting sheep in Neolithic and Bronze Age Greece', in: I. Hodder, G. Isaac and N. Hammond (eds), *Pattern of the Past: Studies in Honour of David Clarke*: pp. 307-39. Cambridge: Cambridge University Press.

— (1981b). 'From determinism to uncertainty: social storage and the rise of the Minoan Palace', in: A. Sheridan and G. Bailey (eds), *Economic Archaeology* (BAR International Series 96): pp. 187-213. Oxford: British Archaeological Reports.

— (1985). 'A study of mandibular teeth from Romano-British contexts at Maxey', in: F. Pryor and C. French (eds), *Archaeology and Environment in the Lower Welland Valley 1 (East Anglian Archaeology 27)*: pp. 219-24.

— (1987). 'Man and other animals in later Greek prehistory'. *Annual of the British School at Athens* **82**: 71-83.

— (1988). 'On redistribution and the origin of Minoan-Mycenaean palatial economies', in: E.B. French and K.A. Wardle (eds), *Problems in Greek Prehistory*: pp. 519-30. Bristol: Bristol Classical Press.

— (1989). 'Like rising damp? An ecological approach to the spread of farming in southeast and central Europe', in: A. Milles, D. Williams and N. Gardner (eds), *The Beginnings of Agriculture* (BAR International Series 496): pp. 23-53. Oxford: British Archaeological Reports.

— (1992a). 'Dhimini and the 'DMP': faunal remains and animal exploitation in Late Neolithic Thessaly'. *Annual of the British School at Athens* **87**: 29-59.

— (1992b). 'Agriculture in the Bronze Age Aegean: towards a model of palatial economy', in: B. Wells (ed.), *Agriculture in Ancient Greece: Proceedings of the Seventh International Symposium at the Swedish Institute at Athens*: pp. 105-16. Stockholm: Swedish Institute at Athens.

— (1992c). 'From reciprocity to redistribution: modelling the exchange of livestock in Neolithic Greece'. *Anthropozoologica* **16**: 19-30.

— (1992d). 'The Mycenaean palatial economy: making the most of the gaps in the evidence'. *Proceedings of the Cambridge Philological Society* **38**: 57-86.

— (1993). 'Banking on livestock: indirect storage in Greek agriculture'. *Bulletin on Sumerian Agriculture* **7**: 63-75.

— (1994). 'The North-South divide: regional paths to complexity in prehistoric Greece', in: C. Mathers and S. Stoddart (eds), *Development and Decline in the Mediterranean Bronze Age*: pp. 195-219. Sheffield: J.R. Collis.

— (1995a). 'Late Bronze Age grain crops and Linear B ideograms *65, *120 and *121'. *Annual of the British School at Athens* **90**: 229-34.

— (1995b). 'Plough and power: the economic and social significance of cultivation of the ox-drawn ard in the Mediterranean'. *Bulletin on Sumerian Agriculture* **8**: 11-22.

— (1995c). 'From sharing to hoarding: the neolithic foundations of Aegean Bronze Age society?' in: R. Laffineur and W.-D. Niemeier (eds), *Politeia: Society and State in the Aegean Bronze Age:*: pp. 11-21. Liège: University of Liège.

— (1996a). 'The development of agriculture and pastoralism in Greece: when, how, who and what?' in: D.R. Harris (ed.), *The Origins and Spread of Agriculture and Pastoralism in Eurasia*: pp.

296-309. London: University College London Press.

— (1996b). 'Pastoralism or household herding? Problems of scale and specialisation in early Greek animal husbandry'. *World Archaeology* **28**: 20-42.

— (1998-99). 'Texts, bones and herders: approaches to animal husbandry in Late Bronze Age Greece'. *Minos* **33-34**: 149-89.

— (1998). 'Mortality models and milking: problems of uniformitarianism, optimality and equifinality reconsidered'. *Anthropozoologica* **27**: 3-20.

— (1999). 'Surplus and share-croppers: the grain production strategies of Mycenaean palaces', in: P. Betancourt, V. Karageorghis, R. Laffineur and W.-D. Niemeier (eds), *MELETHMATA. Studies Presented to Malcolm H. Wiener as he Enters his 65th Year*: pp. 319-26. Liège: University of Liège.

— (2000). 'Land use in postglacial Greece: cultural causes and environmental effects', in: P. Halstead and C. Frederick (eds), *Landscape and Land Use in Postglacial Greece*: pp. 110-28. Sheffield: Sheffield Academic Press.

— (2001). 'Mycenaean wheat, flax and sheep: palatial intervention in farming and its implications for rural society', in: S. Voutsaki and J. Killen (eds), *Economy and Politics in the Mycenaean Palace States*: pp. 38-50. Cambridge: Cambridge Philological Society.

— (2003). 'Texts and bones: contrasting Linear B and archaeozoological evidence for animal exploitation in Mycenaean southern Greece', in: E. Kotjambopoulou, P. Halstead, Y. Hamilakis, P. Elefanti and C. Gamble (eds), *Zooarchaeology in Greece*: pp. 257-62. London: British School at Athens.

— (in press a). 'Resettling the Neolithic: faunal evidence for seasons of consumption and residence at Neolithic sites in Greece', in: D. Bailey and A. Whittle (eds), *Unsettling the Neolithic*. London: Routledge.

— (in press b). 'Faunal remains from FN-EH Nemea Tsoungiza: husbandry, butchery, consumption and discard of animals', in: D. Pullen, P. Halstead, A. Karabatsoli, J. Hansen, S. Allen, K. Krattenmaker, Z. Stos-Gale, M. Kayafa and N. Gale (eds), *Nemea Valley Archaeological Project I: The Early Bronze Age Village on Tsoungiza Hill*. Princeton: American School of Classical Studies at Athens.

— (in prep.). 'Faunal remains from Neolithic Makriyialos'.

Halstead, P., P. Collins, and V. Isaakidou (2002). 'Sorting the sheep from the goats: Morphological distinction between mandibles and mandibular teeth of adult *Ovis* and *Capra*'. *Journal of Archaeological Science* **29**: 545-53.

Halstead, P., and J.O' Shea (1982). 'A friend in need is a friend indeed: social storage and the origins of social ranking', in: C. Renfrew and S. Shennan (eds), *Ranking, Resource and Exchange*: pp. 92-99. Cambridge: Cambridge University Press.

Hamilakis, Y. (1996a). 'Cretan Pleistocene fauna and archaeological remains: the evidence from Sentoni cave (Zoniana, Rethymnon)', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 231-40. Madison: Prehistory Press.

— (1996b). 'Wine, oil and the dialectics of power in bronze age Crete: a review of the evidence'. *Oxford Journal of Archaeology* **15**: 1-32.

— (1998a). 'Stoixeia gia tin prwtominoiki ktinotrofia: Zwoarxaiologikes martyries apo to spilaio Sentonh Zwnianwn Kritis', in: Y. Tzedakis et al. (eds), *Anthropos kai Spelaeoperivallon*: pp. 85-96. Athina: Ypourgeio Politismou. TAPA.

— (1998b). 'Eating the dead: mortuary feasting and the politics of memory in Aegean Bronze age societies', in: K. Branigan (ed.), *Cemetery and Society in the Aegean Bronze Age*: pp. 115-32. Sheffield: Sheffield Academic Press.

Hatzidakis, J. (1921). *Tylissos à l'Époque Minoenne*. Paris: Paul Geuthner.

Higgs, E.S., and M.R. Jarman (1969). 'The origins of agriculture: a reconsideration'. *Antiquity* **43**: 31-41.

Higham, C.W. (1969). 'The metrical attributes of two samples of bovine limb bones'. *Journal of Zoology* **157**: 63-74.

Hood, M.S.F. (1958). 'Knossos', in: M.S.F. Hood (ed.), *Archaeological Reports for 1957*: pp. 21-5. London: Council of the Society for the Promotion of Hellenic Studies and the Managing Committee of the British School of Archaeology at Athens.

— (1959). 'Knossos', in: M.S.F. Hood (ed.), *Archaeological Reports for 1958*: pp. 18-19. London: Council of the Society for the Promotion of Hellenic Studies and the Managing Committee of the British School of Archaeology at Athens.

— (1960). 'Knossos', in: M.S.F. Hood (ed.), *Archaeological Reports for 1959-60*: pp. 21-5. London: Council of the Society for the Promotion of Hellenic Studies and the Managing Committee of the British School of Archaeology at Athens.

Hood, M.S.F. (1962). 'Stratigraphical excavations at Knossos'. *Kretika Chronika (Pepragmena tou A' Diethnous Kretologikou Synedriou)* **15-16**: 92-8.

— (1971). *The Minoans*. London: Thames and Hudson.

— (1990). 'Autochthons or settlers? Evidence for immigration at the beginning of the Bronze Age in Crete', *Pepragmena tou ST' Kretologikou Synedriou,* A1: pp. 367-75. Chania.

— (in prep.). 'The Early Minoan excavations', in: M.S.F. Hood (ed.).

Hood, M.S.F., and D. Smyth (1981). *Archaeological Survey of the Knossos Area*. London: British School at Athens.

Hood, M.S.F., and W. Taylor (1981). *The Bronze Age Palace at Knossos. Plans and Sections*. London: British School at Athens.

Hourmouziadhis, Y. (1979). *To Neolithiko Dhimini*. Volos: Society for Thessalian Studies.

Ingold, T. (1986). *The Appropriation of Nature*. Manchester: Manchester University Press.

Ingold, T., D. Riches, and J. Woodburn (eds) (1991). *Hunters and Gatherers: Property, Power and Ideology*. New York: Berg.

Isaakidou, V. (2003). 'Worked and utilized bone and antler: practical and cultural rationales for the selection of raw materials', in: E. Kotjambopoulou, Y. Hamilakis, P. Halstead, C. Gamble and P. Elefanti (eds), *Zooarchaeology in Greece*: pp. 233-38. London: British School at Athens.

Isaakidou, V. (in prep a). 'The animal bones from the Sanoudakis Plot at Poros Katsamba, Herakleio', in: N. Dimopoulou, D.E. Wilson and P.M. Day (eds). London: British School at Athens.

— (in prep b). 'The animal bones from the South Front Houses', in: C.F. MacDonald (ed.). London: British School at Athens.

Jarman, M.R. (1972). 'Appendix 6: the fauna', in: P.M. Warren (ed.), *Myrtos: an Early Bronze Age Settlement in Crete*: pp. 318-20. London: Thames and Hudson.

— (1996). 'Human influence in the developments of the Cretan mammalian fauna', in: D.S. Reese

(ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 211-30. Madison: Prehistory Press.

Jarman, M.R., and H.N. Jarman (1968). 'The fauna and economy of Neolithic Knossos'. *Annual of the British School at Athens* **63**: 241-64.

Jones, G. (in press). 'Tooth eruption and wear observed in live sheep from Butser Hill, the Cotswold Farm Park and five farms in the Pentland Hills, UK', in D. Ruscillo (ed.), *Advances in Methods of Ageing and Sexing Animal Remains.* Oxford: Oxbow.

Jones, G. (1979). 'Appendix A: the animal remains in Catling (ed.) Knossos 1975: Middle Minoan III and Late Minoan I Houses by the Acropolis'. *Annual of the British School at Athens* **74**: 78-79.

Jordan, B. (1975). *Tierknochenfunde aus der Magula Pevkakia in Thessalien.* [Unpubl. PhD, University of Munich].

Kent, S. (1993). 'Variability in faunal assemblages: the influence of hunting skill, sharing, dogs and mode of cooking on faunal remains at a sedentary Kalahari community'. *Journal of Anthropological Archaeology* **12**: 323-85.

Kierdorf, U. (1993). 'Fork formation and other signs of Osteophagia on a long bone swallowed by a red deer stag (*Cervus elaphus*)'. *International Journal of Osteoarchaeology* **3**: 37-40.

Killen, J.T. (1964). 'The wool industry of Crete in the Late Bronze Age'. *Annual of the British School at Athens* **59**: 1-15.

— (1984). 'The textile industries at Pylos and Knossos', in: T.G. Palaima and C.W. Shelmerdine (eds), *Pylos Comes Alive*: pp. 49-63. New York: Lincoln Center, Fordham University.

— (1985). 'The Linear B tablets and the Mycenaean economy', in: A.M. Davies and Y. Duhoux (eds), *Linear B: a 1984 Survey*: pp. 241-305. Louvain: Louvain University Press.

— (1993a). 'Records of sheep and goats at Mycenaean Knossos and Pylos'. *Bulletin on Sumerian Agriculture* **7**: 209-18.

— (1993b). 'The oxen's names on the Knossos Ch tablets'. *Minos* **27-28**: 101-07.

— (1996). 'Thebes sealings and Knossos tablets', in: L. Godart, E. De Miro and A. Sacconi (eds), *Atti e Memorie del Secondo Congresso Internazionale di Micenologia, 1:Filologia (Incunabula Graeca 98,1).* Rome: Gruppo Editoriale Internazionale.

— (1998). 'The role of the state in wheat and olive production in mycenaean Crete'. *Aevum: Rassegna di Scienze Storiche Linguistiche e Filologiche* **72**: 19-23.

— (2004). 'Pylos tablet Un 1482'. *Minos [2000-1]* **35-6**: 385-89.

Klippel, W.E., and L.M. Snyder (1991). 'Dark age fauna from Kavousi, Crete: the vertebrates from the 1987 and 1988 excavations'. *Hesperia* **60**: 179-86.

Knappett, K., and I. Schoep (2000). 'Continuity and change in Minoan palatial power'. *Antiquity* **74**: 365-71.

Kopaka, K. (1995). 'O Minos Kalokairinos kai oi protes anaskafes stin Knosso', *Proceedings of the 7th International Cretological Congress*: pp. 501-11. Rethymno: Demos Rethymnis kai Istoriki kai Laografiki Etaireia Rethymnis.

Koster, H.A. (1977). *The Ecology of Pastoralism in Relation to Changing Patterns of Land Use in the Northeast Peloponnese.* [Unpubl. PhD, University of Pennsylvania].

Kotsakis, K. (2003). 'From the Neolithic side: the Mesolithic/Neolithic interface in Greece', in: N. Galanidou and C. Perlès (eds), *The Greek Mesolithic: Problems and Perspectives*: pp. 217-21.

London: British School at Athens.

Kotsakis, T. (1990). 'Insular and non-insular vertebrate fossil fauna in Eastern Mediterranean islands'. *Atti Conv. Lincei* **85**: 289-334.

Kratochwil, Z. (1969). 'Species criteria on the distal section of the tibia in *Ovis ammon f. aries* L. and *Capra aegagrus f. hircus* L.' *Acta Veterinaria (Brno)* **38**: 483-90.

Krzyszkowska, O. (1983). 'Wealth and prosperity in pre-palatial Crete: the case of ivory', in: O. Krzyszkowska and L. Nixon (eds), *Minoan Society*: pp. 163-70. Bristol: Bristol Classical Press.

Lax, E. (1996). 'A gazetteer of Cretan palaeontological localities', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 1-32. Madison: Prehistory Press.

Lax, E., and T.F. Strasser (1992). 'Early Holocene extinctions on Crete; the search for the cause'. *Journal of Mediterranean Archaeology*: 203-24.

Legge, A.J. (1981). 'The agricultural economy', in: R.J. Mercer (ed.), *Grimes Graves Excavations 1971-72*: pp. 79-103. London: Her Majesty's Stationery Office.

Legge, A.J., and P.A. Rowley-Conwy (1988). *Starr Carr Revisited: a Re-analysis of the Large Mammals*. London: Birkbeck College, Centre for Extra-Mural Studies.

Lewthwaite, J. (1986). 'The transition to food production: a Mediterranean perspective', in: M. Zvelebil (ed.), *Hunters in Transition*: pp. 53-66. Cambridge: Cambridge University Press.

— (1989). 'Isolating the residuals: the Mesolithic basis of man-animal relationships on the Mediterranean islands', in: C. Bonsall (ed.), *The Mesolithic in Europe*: pp. 541-55. Edinburgh: John Donald.

Lignereux, Y., and J. Peters (1996). 'Techniques de bouchérie et rejets osseux en Gaule Romaine'. *Anthropozoologica* **24**: 45-98.

Lister, A. (1996). 'The morphological distinction between bones and teeth of fallow deer (*Dama dama*) and red deer (*Cervus elaphus*)'. *International Journal of Osteoarchaeology* **6**: 119-43.

Long, J.C., and P.L. Walker (1977). 'An experimental study of the morphological characteristics of tool marks'. *American Antiquity* **42**: 605-16.

Lyman, R.L. (1994). *Vertebrate Taphonomy*. Cambridge: Cambridge University Press.

MacArthur, R.H., and E.O. Wilson (1967). *The Theory of Island Biogeography*. Princeton: Princeton University Press.

MacGillivray, J.A. (1994). 'The early history of the palace at Knossos (MMI-MMII)', in: D. Evely, H. Hughes-Brock and N. Momigliano (eds), *Knossos: a Labyrinth of History, Papers presented in Honour of Sinclair Hood:* pp. 45-56. London: British School at Athens.

— (2000). *Minotaur: Sir Arthur Evans and the Archaeology of the Minoan Myth*. London: Jonathan Cape.

MacGregor, A. (1985). *Bone, antler, ivory and horn: the technology of skeletal materials since the Roman period*. London: Croom Helm.

— (1989). 'Bone, antler and horn industries in the urban context', in: D. Serjeantson and T. Waldron (eds), *Diet and Crafts in Towns: the Evidence of Animal Remains from theRoman to the post-Roman Period* (BAR British Series 199): pp. 107-28. Oxford: British Archaeological Reports.

MacNeal, R.A. (1974). 'The legacy of Arthur Evans'. *California Studies in Classical Antiquity* **6**: 205-20.

Maltby, M. (1985). 'Patterns in faunal assemblage variability', in: C. Gamble and G. Barker (eds), *Beyond Domestication in Prehistoric Europe*: pp. 33-74. London: Academic Press.

Marinatos, S. (1929). 'Protominoikos tafos para to xorion Krasi Pediados'. *Arxaiologikon Deltion* **12**: 102-41.

Masseti, M. (2003a). 'Taxonomic and behavioural aspects of the representation of mammals in Aegean Bronze Age art', in: E. Kotjambopoulou, Y. Hamilakis, P. Halstead, C. Gamble and P. Elefanti (eds), *Zooarchaeology in Greece: Recent Advances*: pp. 273-81. London: British School at Athens.

— (2003b). 'Holocene endemic and non endemic mammals of the Aegean islands', in: E. Kotjambopoulou, Y. Hamilakis, P. Halstead, C. Gamble and P. Elefanti (eds), *Zooarchaeology in Greece: Recent Advances*: pp. 53-64. London: British School at Athens.

Mavridis, F. (2003). 'Early island archaeology and the extinction of endemic fauna in the eastern Mediterranean: problems of interpretation and methodology', in: E. Kotjambopoulou, Y. Hamilakis, P. Halstead, C. Gamble and P. Elefanti (eds), *Zooarchaeology in Greece*: pp. 65-74. London: British School at Athens.

Mayhew, D.F. (1996). 'The extinct Murids of Crete', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*. Madison: Prehistory Press.

McCormick, F. (1992). 'Early faunal evidence for dairying'. *Oxford Journal of Archaeology* **11**: 201-09.

Mol, D., J. de Vos, G. von den Bergh, and P.Y. Sondaar (1996). 'The taxonomy and ancestry of the fossil elephants of Crete: faunal turnover and a comparison with proboscidean faunas of Indonesian islands', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 81-98. Madison: Prehistory Press.

Momigliano, N. (1991). 'MMIA pottery from Evans' excavations at Knossos: a reassessment'. *Annual of the British School at Athens* **86**: 149-271.

— (1999). *Duncan Mackenzie: a Cautious and Canny Highlander and the Palace of Minos at Knossos*. London: Institute of Classical Studies.

Momigliano, N., and D.E. Wilson (1996). 'Knossos 1993: excavations outside the south front of the Palace'. *Annual of the British School at Athens* **91**: 1-57.

Moody, J. (1987a). *The Environmental and Cultural Prehistory of the Khania Region.* [Unpubl. PhD, Minnesota].

— (1987b). 'The Minoan palace as a prestige artifact', in: R. Hägg and N. Marinatos (eds), *The Function of the Minoan Palaces*: pp. 235-41. Stockholm: Swedish Institute at Athens.

Moody, J., O. Rackham, and G. Rapp (1996). 'Environmental archaeology of prehistoric NW Crete'. *Journal of Field Archaeology* **23**: 273-97.

Morris, M. (2002). *Soil Science and Archaeology: Three Test Cases from Minoan Crete.* Philadelpheia: The Institute for Aegean Prehistory Academic Press.

Mosimann, J.E., and P.S. Martin (1975). 'Simulating overkill by Paleoindians'. *American Scientist* **63**: 304-13.

Munson, P.J. (2000). 'Age-related differential destruction of bones and its effect on archaeological mortality profiles of domestic sheep and goats'. *Journal of Archaeological Science* **27**: 391-407.

Mylona, D. (1999). 'Chamalevri: the animal bones; Splantzia: o hieros xoros', in: Y. Tzedakis and H. Martlew (eds), *Minoans and Myceneans, Flavours of their Time*: pp. 64-67, 106. Athens:

Ministry of Culture-National Archaeological Museum.

Nakou, G. (1995). 'The cutting edge: a new look at early Aegean metallurgy'. *Journal of Mediterranean Archaeology* **8**: 1-32.

Nicholson, R. (1992). 'Bone survival: the effects of sedimentary abrasion and trampling on fresh and cooked bone'. *International Journal of Osteoarchaeology* **2**: 139-54.

— (1996). 'Bone degradation, burial medium and species representation: debunking the myths, an experiment-based approach'. *Journal of Archaeological Science* **23**: 513-34.

Nobis, G. (1988). 'Die Haus- und Wildtiere aus dem Berheiligtum Kato Syme SO-Kreta - Grabungen 1972-1984'. *Tier und Museum* **1**: 42-47.

— (1989). 'Tierreste aus Knossos auf Kreta'. *Archäologische Informationen* **12**: 216-23.

— (1990). 'Der 'Minotaurus' von Knossos auf Kreta - im Lichte moderner archaozoologischer Forschung'. *Tier und Museum* **2**: 15-19.

— (1993). 'Zur antiken Wild- und Houstierfauna Kretas - nach Studien an Tierresten aus den archäologischen Grabungen Poros bei Iraklion und Eleftherna bei Arkadhi'. *Tier und Museum* **2**: 109-20.

Noddle, B. (1990). 'Flesh on the bones'. *Circaea* **7**: 31-51.

Nowicki, C. (1999). 'Economy and refugee life in the Cretan mountains at the turn of the Bronze and Iron Ages', in: A. Chaniotis (ed.), *From Minoan Farmers to Roman Traders: Sidelights on the Economy of Ancient Crete*: pp. 145-71. Stuttgart: Franz Steiner.

O'Connor, T.P. (1993). 'Process and terminology in mammal carcass reduction'. *International Journal of Osteoarchaeology* **3**: 63-67.

— (2000). *The Archaeology of Animal Bones*. Stroud: Sutton.

Olivier, J.-P. (1967). 'La série Dn de Cnossos'. *Studies in Mediterranean Archaeology* **2**: 71-93.

— (1988). 'KN: Da-Dg', in: J.-P. Olivier and T.G. Palaima (eds), *Texts, Tablets and Scribes*. (Minos Supplementary Volume): pp. 219-67. Salamanca: Salamanca University.

Palaima, T.G. (1992). 'The Knossos oxen dossier: the use of oxen in Mycenaean Crete, 1: general background and scribe 107', in: J.-P. Olivier (ed.), *Mykenaïka. Actes du 9e Colloque Internationale sur les Textes Mycéniens et Égéens*: pp. 463-74. Paris: École Française d' Athènes.

Panagiotaki, M. (1999). *The Central Palace Sanctuary at Knossos*. London: British School at Athens.

Pappa, M., P. Halstead, K. Kotsakis, and D. Urem-Kotsos (2004). 'Evidence for large-scale feasting at Late Neolithic Makriyalos, N. Greece', in P. Halstead and J. Barrett (eds), *Food, Cuisine and Society in Prehistoric Greece*: pp: 16-44. Oxford: Oxbow.

Payne, S. (1969). 'A metrical distinction between sheep and goat metacarpals', in: P.J. Ucko and G.W. Dimbleby (eds), *The Domestication and Exploitation of Plants and Animals:* pp: 295-305. London: Duckworth.

— (1972). 'Partial recovery and sample bias: the results of some sieving experiments', in: E.S. Higgs (ed.), *Papers in Economic Prehistory*: pp. 49-64. Cambridge: Cambridge University Press.

— (1973). 'Kill-off patterns in sheep and goats: the mandibles from Aşvan Kalé'. *Anatolian Studies* **23**: 281-303.

— (1985a). 'Zoo-archaeology in Greece: a reader's guide', in: N.C. Wilkie and W.D.E. Coulson

(eds), *Studies in Honor of William A. McDonald*: pp. 211-44. Minneapolis: University of Minnesota Press.

— (1985b). 'Morphological distinctions between the mandibular teeth of young sheep, *Ovis*, and goats, *Capra*.' *Journal of Archaeological Science* **12**: 139-47.

— (1995). 'The small mammals. Appendix 5', in: J.W. Shaw and M.C. Shaw (eds), *Kommos I. The Kommos Region, Ecology and Minoan Industries*: pp. 278-90. Princeton: Princeton University Press.

Payne, S., and G. Bull (1988). 'Components of variation in measurements of pig bones and teeth and the use of measurements to distinguish wild from domestic pig remains'. *Archaeozoologia* **2**: 27-66.

Payne, S., and P.J. Munson (1985). 'Ruby and how many squirrels? The destruction of bones by dogs', in: N.R.J. Fieller, D.D. Gilbertson and N.G.A. Ralph (eds), *Palaeobiological Investigations - Research Design, Methods and Data Analysis* (BAR International Series 266): pp. 31-40. Oxford: British Archaeological Reports.

Peatfield, A. (1992). 'Rural ritual in Bronze Age Crete: the peak sanctuary at Atsipadhes'. *Cambridge Archaeological Journal* **2 (1)**: 59-87.

Peltenburg, E.J., S. Colledge, P. Croft, A. Jackson, C. McCartney, and M.A. Murray (2000). 'Agro-pastoralist colonisation of Cyprus in the 10th millennium BP: initial assessments'. *Antiquity* **74**: 844-53.

Pendlebury, J.D.S. (1939). *The Archaeology of Crete: an Introduction*. London: Methuen.

Pérez Ripoll, M. (2002). 'Extinción de la fauna endémica y colonización de las grandes islas del Mediterráneo', in: E. Badal, J. Bernabeu and B. Martí (eds), *El Paisaje en el Neolítico Mediterráneo*: pp. 147-63. València: University of València.

Perlès, C. (1987). *Les industries lithiques taillées de Franchthi (Argolide, Grèce). I. Presentation générale et industries paléolithiques (Excavations at Franchthi Cave, Greece, Fascile 3)*. Bloomington: Indiana University Press.

Persson, P.O. (1993). 'Ure in Chania auf Kreta'. *Tier und Kreta* **3**: 121-23.

Pollock, S. (1999). *Ancient Mesopotamia*. Cambridge: Cambridge University Press.

Pope, K. (1993). 'Geology and soils', in: Watrous, L.V. *et al.* (1993), pp: 197-204.

Poursat, J.-C. (1996). *Artisans Minoens: les Maisons-Ateliers du Quartier Mu*. Paris: École Française d'Athènes (Etudes Cretoises, 32).

Prummel, W. (1987a). 'Atlas for identification of foetal skeletal elements of cattle, horse, sheep and pig: part 1'. *Archaeozoologia* **1**: 23-30.

— (1987b). 'Atlas for identification of foetal skeletal elements of cattle, horse, sheep and pig: part 2'. *Archaeozoologia* **1**: 11-42.

— (1988a). 'Atlas for identification of foetal skeletal elements of cattle, horse, sheep and pig: Part 3'. *Archaeozoologia* **2**: 13-26.

— (1988b). *Distinguishing Features on Postcranial Skeletal Elements of Cattle, Bos primigenius f. taurus, and RedDeer, Cervus elaphus*. Kiel (Schriften aus den Archäologisch-Zoologischen Arbeitsgruppe Schleswig-Kiel, 12).

— (1989). 'Appendix to Atlas for identification of foetal skeletal elements of cattle, horse, sheep and pig'. *Archaeozoologia* **3**: 71-89.

Prummel, W., and H.-J. Frisch (1986). 'A guide for the distinction of species, sex and body side in bones of sheep and goat'. *Journal of Archaeological Science* **13**: 567-77.

Pullen, D.J. (1992). 'Ox and plough in the Early Bronze Age Aegean'. *American Journal of Archaeology* **96**: 45-54.

Rackham, O., and J. Moody (1996). *The Making of the Cretan Landscape*. Manchester: Manchester University Press.

Redding, R. (1981). *Decision Making in Subsistence Herding of Sheep and Goats in the Middle East*. [Unpubl. PhD, University of Michigan].

Redding, R. (1984). 'A herder's decisions: the sheep/goat ratio', in: J. Clutton-Brock and C. Grigson (eds), *Animals and Archaeology 3* (BAR International Series 202): pp. 223-41. Oxford: British Archaeological Reports.

Reese, D.S. (1995a). 'The faunal remains', in: P. Betancourt (ed.), *Pseira I: The Minoan Buildings on the West Side of Area A*: pp. 11, 45, 56, 83, 129. Philadelphia: University of Pensylvania Museum.

— (1995b). 'Chapter 5: the Minoan fauna', in: J.W. Shaw and M.C. Shaw (eds), *Kommos I: The Kommos Region and Houses of the Minoan Town*: pp. 163-93. Princeton, New Jersey: Princeton University Press.

— (ed.) (1996). *Pleistocene and Holocene Fauna of Crete and its First Settlers*. Madison: Prehistory Press.

Reese, D.S., G. Belluomini, and M. Ikeya (1996). 'Absolute dates for the Pleistocene fauna of Crete', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 47-52. Madison: Prehistory Press.

Rehak, P., and J.G.Younger (2001). 'Review of Aegean Prehistory VII: Neopalatial, Final Palatial and Postalatial Crete', in: T. Cullen (ed.), *Aegean Prehistory: A Review*: pp. 383-465. Boston: American Journal of Archaeology, Archaeological Institute of America.

Renfrew, A.C. (1980). 'The Great Tradition versus the Great Divide: archaeology as anthropology?' *American Journal of Archaeology* **84**: 287-98.

Renfrew, A.C., and A. Aspinall (1990). 'Aegean obsidian and Franchthi cave', in: C. Perlès (ed.), *Les industries lithiques taillées de Franchthi (Argolide, Grèce). II. Les industries du Mésolithique et du Néolithique initial (Excavations at Franchthi Cave, Greece, Fascicle 5)*: pp. 257-70. Bloomington: Indiana University Press.

Renfrew, C. (1972). *The Emergence of Civilisation: the Cyclades and the Aegean in the Third Millennium BC*. London: Methuen.

Reumer, J.W.F. (1994). 'Phylogeny and distribution of the *Crocidosoricinae* (Mammalia, Soricidae)', in: J.F. Merritt, G.L.Kirkland Jr and R.K. Rose (eds), *Advances in the Biology of Shrews*: pp. 345-56. Carnegie Museum of Natural History Special Publication.

— (1996). 'Shrews (Soricidae) on islands with special reference to *Crocidura zimmermanni* from Crete', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 173-80. Madison: Prehistory Press.

Richards, M.P., J.A. Pearson, T.I. Molleson, N. Russell, and L. Martin (2003). 'Stable isotope evidence of diet at Neolithic Çatal Höyük, Turkey'. *Journal of Archaeological Science* **30**: 67-76.

Roberts, N. (1979). 'The location and environment of Knossos'. *Annual of the British School at Athens* **74**: 231-41.

— (1981). 'The physical environment of the Knossos area', in: S. Hood and D. Smyth (eds), *An Archaeological Survey of the Knossos Area*: p. 5. London: Thames and Hudson.

Rowley-Conwy, P. (1995). 'Wild or domestic? On the evidence for the earliest domestic cattle and pigs in south Scandinavia and Iberia'. *International Journal of Osteoarchaeology* **5**: 115-26.

— (1998). 'Improved separation of Neolithic Metapodials of sheep (*Ovis*) and goats (*Capra*) from Arene Candide Cave, Liguria, Italy' in *Journal of Archaeological Science* **25**: 251-58.

— (2000). 'Milking caprines, hunting pigs: the Neolithic economy of Arene Candide in its West Mediterranean context', in: P. Rowley-Conwy (ed.), *Animal Bones, Human Societies*: pp. 124-32. Oxford: Oxbow.

Runnels, C.N. (1995). 'Review of Aegean Prehistory IV: the Stone Age of Greece from the Palaeolithic to the advent of the Neolithic'. *American Journal of Archaeology* **99**: 699-728.

Rushe, C., and P. Halstead (1995). 'Bone, shell and soil samples in the Neolithic levels from the Throne Room system at Knossos'. *Annual of the British School at Athens* **90**: 13-5.

Rutkowski, B. (1986). *The Cult Places of the Aegean*. New Haven and London: Yale University Press.

Ryan, K., and P.J. Crabtree (eds) (1995). *The Symbolic Role of Animals in Archaeology*. Philadelpheia: MASCA.

Schiffer, M.B. (1995). *Behavioural Archaeology: First Principles*. Salt Lake City: University of Utah Press.

Schmandt-Besserat, D. (2001). 'Feasting in the ancient Near East', in: M. Dietler and B. Hayden (eds), *Feasts: Archaeological and Ethnographic Perspectives on Food, Politics and Power*: pp. 391-403. Washington: Smithsonian Institution Press.

Schmid, E. (1972). *Atlas of Animal Bones*. Amsterdam: Elsevier.

Schoep, I. (1999). 'The origins of writing and administration on Crete'. *Oxford Journal of Archaeology* **18**: 265-76.

— (2001). 'Managing the hinterland: the rural concerns of urban administration', in: K. Branigan (ed.), *Urbanism in the Aegean Bronze Age*: pp. 87-102. Sheffield: Sheffield Academic Press.

Schüle, W. (1993). 'Mammals, vegetation and the initial human settlement of the Mediterranean islands: a paleo-ecological approach'. *Journal of Biogeography* **20**: 399-412.

Sherratt, A.S. (1981). 'Plough and pastoralism: aspects of the secondary products revolution', in: I. Hodder, G. Isaac and N. Hammond (eds), *Pattern of the Past: Studies in Honour of David Clarke*: pp. 261-305. Cambridge: Cambridge University Press.

— (1983). 'The secondary exploitation of animals in the Old World'. *World Archaeology* **15**: 90-104.

Shipman, P., G. Foster, and M. Schoeninger (1984). 'Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage'. *Journal of Archaeological Science* **11**: 307-25.

Silver, I. (1969). 'The ageing of domestic animals', in: E.S. Higgs and D. Brothwell (eds), *Science in Archaeology*: pp. 283-302. London: Thames and Hudson.

Simmons, A.H. (1999). *Faunal Extinctions in an Island Society: Pygmy Hippo Hunters of Cyprus*. Amsterdam/New York: Kluwer/Plenum.

— (2001). 'The first humans and the last pygmy hippopotami of Cyprus', in: S. Swiny (ed.), *The*

Earliest Prehistory of Cyprus: from Colonisation to Exploitation: pp. 1-18. Boston, MA: American Schools of Oriental Research.

Snodgrass, A.M. (1985). 'The New Archaeology and the classical archaeologist'. *American Journal of Archaeology* **89**: 31-7.

Soles, J.S. (1988). 'Social ranking in prepalatial cemeteries', in: E.B. French and K.A. Wardle (eds), *Problems in Greek Prehistory*: pp. 49-61. Bristol: Bristol Classical Press.

Sondaar, P. (1986). 'The island sweepstakes'. *Natural History* **95**: 50-57.

Sondaar, P.Y., M.D. Dermitzakis, H. Drinia, and J.D. Vos (1998). 'Palaeoecological factors that controlled the survival and adaptation of the Pleistocene man on the Mediterranean islands'. *Geologika Xronika ton Ellinikon Xoron* **38**: 25-35.

Sondaar, P.Y., M.D. Dermitzakis, and J.D. Vos (1996). 'The palaeogeography and faunal evolution of the land mammals of Crete', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 61-68. Madison: Prehistory Press.

Spaan, A. (1996). '*Hippopotamus creutzburgi*: the case of the Cretan hippopotamus', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 99-110. Madison: Prehistory Press.

Steensma, K.J., and D.S. Reese (1996). 'The mustelins of Crete', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 159-66. Madison: Prehistory Press.

Strasser, T. (1992). *Settlement and Land Use on Neolithic Crete.* [Unpubl. PhD, Indiana University].

Sutcliffe, A. (1973). 'Similarity of bones and antlers gnawed by deer to human artifacts'. *Nature* **246**: 428-30.

— (1977). 'Further notes on bones and antlers chewed by deer and other ungulates'. *Deer* **4**: 73-82.

Thomas, J. (1999). *Understanding the Neolithic.* London: Routledge.

Tomkins, P. (2001). *The Production, Circulation and Consumption of Ceramic Vessels at Early Neolithic Knossos, Crete.* [Unpubl. PhD, University of Sheffield].

— (2004). 'Filling in the 'Neolithic Background': social life and social transformation in the Aegean before the Bronze Age', in: J. Barrett and P. Halstead (eds), *The Emergence of Civilisation Revisited.* pp.: 38-63. Oxford: Oxbow.

Tomkins, P., and P.M. Day (2001). 'Production and exchange of the earliest ceramic vessels in the Aegean: a view from Early Neolithic Knossos, Crete'. *Antiquity* **75**: 259-60.

Tomkins, P., P. Day, and V. Kilikoglou (2004). 'Knossos and the earlier Neolithic landscape of the Herakleio basin', in: G. Cadogan, E. Hatzaki and A. Vasilakis, (eds), *Knossos City, Palace, State.* pp.: 38-63. London: British School at Athens.

Trantalidou, K. (2003). 'Faunal remains from the earliest strata of the Cave of Cyclope, Youra', in: N. Galanidou and C. Perlès (eds), *The Greek Mesolithic: Problems and Perspectives*: pp. 143-72. London: British School at Athens. (British School at Athens Studies).

Tsoukala, E. (1996). 'The animal bones from Smari: a preliminary report', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 273-76. Madison: Prehistory Press.

Turland, N.J., L. Chilton, and J.R. Press (1993). *Flora of the Cretan Area: Annotated Checklist and Atlas.* London: The Natural History Museum.

Tzedakis, Y., and H. Martlew (eds) (1999). *Minoans and Mycenaeans: Flavours of their Time.* Athens: Greek Ministry of Culture, National Archaeological Museum.

Vanschoonwinkel, J. (1996). 'Les animaux dans l'art minoen', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 351-412. Madison: Prehistory Press.

van der Veen, M., and N. Fieller (1982). 'Sampling seeds'. *Journal of Archaeological Science* **9**: 287-98.

Vickery, K.F. (1936). *Food in Early Greece.* Illinois: University of Illinois.

Vigne, J.-D. (1988). 'Biogéographie insulaire et anthropozoologie des sociétés néolithiques méditerranéennes: hérisson, renard et micromammifères'. *Anthropozoologica* **8**: 31-52.

— (1996). 'Did man provoke extinctions of endemic large mammals on the Mediterranean islands? The view from Corsica'. *Journal of Mediterranean Archaeology* **9**: 117-20.

— (1999). 'The large "true" Mediterranean islands as a model for the Holocene human impact on the European vertebrate fauna? Recent data and new reflections', in: N. Benecke (ed.), *The Holocene History of the European Vertebrate Fauna: Modern Aspects of Research*: pp. 295-321. Rahden: Marie Leidorf.

— (2000). 'Les débuts Néolithiques de l'élevage des ongulés au Proche Orient et en Méditerranée: acquis récents et questions', in: J. Guilaine (ed.), *Premiers Paysans du Monde: Naissances des Agricultures*: pp. 143-68. Paris: Errance.

Vigne, J.-D., S. Bailon, and J. Cuisin (1997). 'Biostratigraphy of amphibians, reptiles, birds and mammals in Corsica and the role of man in the Holocene faunal turnover'. *Anthropozoologica* **25-26**: 587-604.

Vigne, J.-D., and J. Blondel (1993). 'Space, time and man as determinants of diversity of birds and mammals in the Mediterranean region', in: R.E. Ricklefs and D. Schluter (eds), *Species Diversity in Ecological Communities*: pp. 135-46. Chicago: University of Chicago Press.

Vigne, J.-D., H. Buitenhuis, and S. Davis (2000). 'Les premiers pas de la domestication animale à l' Ouest de l' Euphrate: Chypre et l' Anatolie centrale'. *Paléorient* **25**: 49-62.

de Vos, J. (1996). 'Taxonomy, ancestry and speciation of the endemic Pleistocene deer of Crete compared with the Taxonomy, ancestry and speciation of Darwin's finches', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 111-24. Madison: Prehistory Press.

Walker, P.L. (1978). 'Butchering and stone tool function'. *American Antiquity* **43**: 710-15.

Warren, P.M., and Y. Tzedhakis (1974). 'Debla. An Early Minoan settlement in western Crete'. *Annual of the British School at Athens* **69**: 299-342.

Watrous, L.V. (1977). 'Aegean settlements and transhumance', *Temple University Aegean Symposium*: pp. 2-6.

— (1982). *Lasithi. A History of Settlement on a Highland Plain of Crete.* Princeton: Princeton University Press.

— (1994). 'Review of Aegean Prehistory III: Crete from earliest prehistory through the Protopalatial period'. *American Journal of Archaeology* **98**: 695-753.

— (1996). *The Cave Sanctuary of Zeus at Psychro: A Study of Extra-Urban Sanctuaries in Minoan and Early Iron Age Crete.* Liège: University of Liège.

— (2001). 'Review of Aegean Prehistory III: Crete from earliest prehistory through the

Protopalatial period. Addendum 1994-1999', in: T. Cullen (ed.), *Aegean Prehistory: A Review*: pp. 216-24. Boston: American Journal of Archaeology, Archaeological Institute of America.

Watrous, L.V., D. Xatzi-Vallianou, K. Pope, N. Mourtzas, J. Shay, C.T. Shay, J. Bennet, D. Tsoungarakis, C. Vallianos, and H. Blitzer (1993). 'A survey of the Western Messara plain in Crete'. *Hesperia* **62 (2)**: 191-248.

Watson, P.J. (1979). *Archaeological Ethnography in Western Iran*. Tucson, Arizona: University of Arizona Press.

Whitelaw, T.M. (1983). 'The settlement at Fournou Korifi, Myrtos and aspects of Early Minoan social organization', in: O. Krzyszkowska and L. Nixon (eds), *Minoan Society*: pp. 323-45. Bristol: Bristol Classical Press.

— (1992). 'Lost in the labyrinth? Comments on Broodbank's "Social change at Knossos before the Bronze Age"'. *Journal of Mediterranean Archaeology* **15**: 225-38.

— (2001). 'From sites to communities: defining the human dimensions of Minoan urbanism', in: K. Branigan (ed.), *Urbanism in the Aegean Bronze Age*: pp. 15-37. Sheffield: Sheffield Academic Press.

Whitelaw, T.M., P.M. Day, E. Kyriatzi, V. Kilikoglou, and D.E. Wilson (1997). 'Ceramic traditions at EMIIB Myrtos Fournou Koryfi', in: R. Laffineur and P.P. Betancourt (eds), *Techne: Craftsmen, Craftswomen and Craftsmanship in the Aegean Bronze Age*: pp. 265-74. Liège: University of Liège.

Whittaker, C.R. (1998). *Island Biogeography: Ecology, Evolution and Conservation*. Oxford: Oxford University Press.

Whittle, A. (1997). 'Moving on and moving around: neolithic settlement mobility', in: P. Topping (ed.), *Neolithic Landscapes*: pp. 15-22. Oxford: Oxbow.

Wilkens, B. (1996). 'The fauna from Italian excavations on Crete', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 241-62. Madison: Prehistory Press.

— (2003). 'Hunting and breeding in ancient Crete', in: E. Kotjambopoulou, Y. Hamilakis, P. Halstead, C. Gamble and P. Elefanti (eds), *Zooarchaeology in Greece: Recent Advances*: pp. 85-90. London: British School at Athens.

Willemsen, G.F. (1996). 'The Cretan otter *Lutrogale cretensis*', in: D.S. Reese (ed.), *Pleistocene and Holocene Fauna of Crete and its First Settlers*: pp. 153-57. Madison: Prehistory Press.

Wilson, D.E. (1985). 'The pottery and architecture of the EMIIA West Court House at Knossos'. *Annual of the British School at Athens* **80**: 281-364.

— (1994). 'Knossos before the palaces: an overview of the Early Bronze Age (EMI-EMIII)', in: D. Evely, H. Hughes-Brock and N. Momigliano (eds), *Knossos: a Labyrinth of History, Papers presented in Honour of Sinclair Hood:* pp. 23-44. London: British School at Athens.

Wilson, D.E., and P.M. Day (1994). 'Ceramic regionalism in prepalatial Central Crete: the Mesara imports at EMI to EMIIA Knossos'. *Annual of the British School at Athens* **89**: 1-87.

— (2000). 'EMI chronology and social practice: pottery from the early Palace tests at Knossos'. *Annual of the British School at Athens* **95**: 21-63.

Winder, N.P. (1986). *Faunal Analysis; Studies in the Analysis and Interpretation of Animal Bones from Large, Multi-Phase Archaeological Excavations*. [Unpubl. PhD, Southampton].

— (1991). 'Interpreting a site: the case for a reassessment of the Knossos Neolithic'. *Archaeological Reviews from Cambridge* **10**: 37-52.

— (1994). 'Designing a database for animal bones', in: R. Luff and P. Rowley-Conwy (eds), *Whither Environmental Archaeology*: pp. 33-9. Oxford: Oxbow.

Wright, J.C. (1996). 'Empty cups and empty jugs: the social role of wine in Minoan and mycenaean societies', in: P.E. McGovern, S.J. Fleming and S.H. Katz (eds), *The Origins and History of Wine*: pp. 287-309. Philadelphia: Gordon and Breach.

Xanthoudides, S. (1924). *The Vaulted Tombs of Mesara: an Account of Some Early Cemeteries of Southern Crete*. London: Hodder and Stoughton.

Zeder, M.A. (1999). 'Animal domestication in the Zagros: a review of past and current research'. *Paléorient* **25**: 11-25.

— (2003). 'Hiding in plain sight: the value of museum collections in the study of the origins of animal domestication', in: G. Grupe and J. Peters (eds), *Decyphering Ancient Bones: the Research Potential of Bioarchaeological Collections*: pp. 125-38: Rahden: Marie Leidorf.

Zeimbeki, M. (2004). 'The organisation of votive production and distribution in the peak sanctuaries of state society Crete: a perspective offered by the Juktas clay animal figures', in: G. Cadogan, E. Hatzaki and A. Vasilakis (eds), *Knossos City, Palace, State*. Pp. 351-61. London: British School at Athens.